VOLUME 22 • NUMBER 4

December, 1951

the RESEARCH Quarterly

PART I OF TWO PARTS

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The Research Quarterly

of the American Association for Health, Physical Education, and Recreation

Volume 22 DECEMBER 1951 Number 4

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NOTE: For *Guide to Authors*, see October 1951 issue.

Published in March, May, October, and December by the American Association for Health, Physical Education, and Recreation, 1201 Sixteenth Street, N.W., Washington 6, D. C. Subscription available to libraries, institutions, and departments at $3.00 per year. Of the Professional Membership ($10.00 per year) or Student Professional Membership ($4.00 per year), $3.00 covers subscription to the *Quarterly*. *Subscriptions to individuals through membership only.* Single copies $1.25.
Send membership dues or subscriptions to Circulation Dept., 1201 Sixteenth Street, N.W., Washington 6, D. C. Editorial Office, 1201 Sixteenth Street, N.W., Washington 6, D. C. Entered as second-class matter at the Post Office at Washington, D. C., under the act of March 3, 1879. Additional entry at Baltimore, Md.

The Research Quarterly

of the American Association for Health, Physical Education, and Recreation

Volume 22 DECEMBER, 1951 Number 4

Physical Fitness Tests on New Zealand Schoolchildren[1]

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In recent years the view has gained much ground that physical fitness is more than a matter of muscular size and strength—that it is rather an end-product of general health. The emphasis in physical education has shifted from muscle-building to the task of attempting to fit a healthy individual into a health environment. See Clarke (5).

The importance of this is shown, for example, by the educational studies of Douglas (11), who found that health status gave as high a prediction of scholastic success as any other commonly used prediction. Physical fitness is of recognized great economic importance to both the individual and the community, from the point of view of employability; physiological efficiency runs parallel to labor output and earning power. See Jokl and Cluver (19). This "physiological efficiency" may be considered to be one of three inter-related components—physical, or structural; physiological; and psychological, that must be "normal" or in good functional condition in order to maintain a state of good health in the individual, and his satisfactory relationship to the community. See Kessler (20).

There is evidence to show that this physiological component is related to the state of health. Locke (21, 22) and Locke and Main (23) showed that physiological efficiency may be related to susceptibility to colds and to pneumococcal infections. Botha and Jokl (2) discuss the relationship of physiological efficiency to health and nutrition, while the results of certain physical fitness tests correlate well with the results of medical examinations. Hence, measurement of physiological efficiency, if the other components of health are normal, may provide some index of the general health of the individual.

[1] A condensation of a thesis originally entitled *The Testing of Physical Fitness* presented as part of the requirements of the course in Preventive Medicine for the degree of M.B., Ch. B. in the University of New Zealand, October 1948.

Purpose of the Study

In this study an attempt is made to (a) apply suitable methods of testing physical fitness to mass investigation; (b) find "normal" values for the groups investigated, and compare these with comparable figures obtained by other investigators; (c) correlate the results obtained with other measures of health and scholastic achievement.

Subjects

The subjects of this study comprised 125 schoolchildren from Forms I and II of the Dunedin North Intermediate School, Dunedin, N. Z., who were investigated during the second (winter) term of 1948. Since not all of the information required was available for all the children, there are small variations in the total numbers in the various investigations. The children were selected at random from classes as they came to Physical Education periods. They represent about half the total number of children in the school. The average height, weight, and surface area are shown in Table 1.

TABLE 1

Mean body measurements

Type of Measurement	Boys (63)		Girls (62)	
	Mean	Range	Mean	Range
Age (yr.)	12.75 ± 0.06	10.91 – 14.91	12.43 ± 0.07	11.0 – 14.67
Height (in.)	57.65 ± 0.26	48 – 67	58.19 ± 0.25	48 – 14.67
Weight (lb.)	91.98 ± 1.52	60 – 140	92.90 ± 1.23	60 – 120
Surface area (sq. meters)	1.323 ± 0.013	0.95 – 1.70	1.325 ± 0.012	1.0 – 1.75

NOTE: *Boys + Girls* (122)—Mean, 1.323 ± .013; Range 0.95 – 1.75.

TABLE 2

Comparative heights, weights, and surface areas

Group	Height (*inches*)		Weight (*pounds*)		Surface area (*square meters*)	
	Boys	Girls	Boys	Girls	Boys	Girls
Group tested	57.65	58.2	92.0	92.9	1.32	1.32
New Zealand (European, country)*	59.0	60.1	91.8	97.5	1.32	1.38
American†	58.5	59.1	86.4	88.7	1.29	1.31
Canadian†	58.4	58.9	87.4	90.2	1.29	1.31
English†	56.9	57.8	83.3	87.0	1.24	1.28
South African†	59.1	59.7	86.3	93.0	1.31	1.34

* Obtained from Lonie (24).
† Obtained from Cluver, Jokl, and Rorich (6).

Twenty-five children were considered over- or under-weight according to the Toronto tables.[2] The mean surface area of the remaining 97 was 1.312 ± 0.009 sq. m. with a standard deviation of 0.143 sq. m.

[2] M. F. Boyd, *Preventive Medicine* (7th ed.), Philadelphia: W. B. Saunders, 1945, pp. 486–87.

Of the fathers 67 per cent were tradesmen or laborers; 33 per cent were shop, office, or professional workers. School attendance figures for 1947 and the first term of 1948 were obtained from official records, as were I. Q. and health histories. None of the children suffered any gross defect, nor did any have a health history of significance.

Method Used

After reviewing carefully available methods, it was decided that a step-up' pulse-rate test[3, 4, 5] conformed to these requirements better than any others available.

A modification of the Tuttle[6] type of test was used.

1. *Resting Pulse Rate* was measured by seating the subject at rest and counting the pulse for one minute. After a short period this was repeated, until a constant rate was obtained, the subject resting in the intervals. In this way an accurate figure can be obtained. The maximum error, allowing one beat at each end of the counting, is about 3 per cent for a pulse rate of 80.

2. *Standard Exercise*: The subject was asked to step up and down on a stool 13 inches high at a rate and rhythm determined by the examiner; that is, as rapidly as consistent with proper stepping. The steps must be taken so that the knee is extended each time. See Tuttle (31). This was best taught by a demonstration.

3. *Pulse rate after exercise* was counted, immediately after its completion, by seating the subject at once and counting the pulse for exactly two minutes. Counting began just 5 seconds after the exercise stopped in order to allow the subject to be seated and the examiner to find the pulse satisfactorily. To allow for this lag the beats counted in the first 5 seconds of counting were doubled. This does not introduce a serious error, for Cotton and Dill (8) showed that after exercise of sufficient intensity the heart rate falls very little (about one beat) in the first 10 seconds. It was convenient to count rapid rates in groups of 10 or 20 beats, and also half-minute totals were recorded so that the rate of deceleration could be studied, in about 70 random cases. The total number of beats in two minutes divided by the resting pulse-rate per minute was called the "pulse ratio."

Procedure

In order to collaborate with the school staff and minimize interruption into school program the tests were conducted in Physical Education periods. Equal numbers of boys and girls were selected at random. For the complete tests each operator could handle four children in a 40-minute period. The four children were seated at rest and the pulse rates counted in turn, so that by the time

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[3] L. A. Larson, *J. exp. Ed.*, **7**, 214, (1939) and *Res. Quart.* **18**, 109 (1947).

[4] L. Brouha, N. W. Fradd, and B. M. Savage, *Res. Quart.* **15**, 211 (1944).

[5] W. W. Tuttle, and R. E. Dickinson, *Res. Quart.* **9**, 73 (1938).

[6] Since this paper was written there has appeared a study by Cook and Wherry (7) which adds support to these views.

the last was completed the first was well settled and the pulse steady. It was seldom necessary to repeat the resting count more than twice. Each pupil was then taken in turn for the standard exercise and the pulse counted for two minutes.

PHYSICAL MEASUREMENTS

Children were weighed to the nearest pound, without shoes or heavy outer clothes, on a direct-reading scale; no correction was made for remaining clothing. Height was measured to the nearest half-inch, again without shoes. All the children were regarded as essentially "normal" but some were outside the limits of weight defined by the Toronto Tables.[2] These limits recommended were 8 per cent under- and 15 per cent over-weight, corresponding to 6 to 11 pounds respectively, for the average weight of 75 pounds.

STATISTICAL METHODS

Statistical techniques follow Pearl (28). Mean value was followed by their probable error (P. E.)

Results

1. PHYSICAL MEASUREMENTS

The average age, weight, height, and surface area of the children investigated are shown in Table 1. If those who vary more than 6 pounds underweight or 11 pounds overweight (according to the standard figures used) are eliminated, neither mean surface area nor mean pulse ratio is affected.

Table 2 presents average heights, weights, and surface areas of American, Canadian, English, and South African children of 11–14 years for comparison with the group investigated.

2. RELIABILITY OF THE METHOD

In certain random cases the resting pulse rate and the pulse after exercise were checked by two observers with agreement within one or two beats, or an outside error of approximately 3 per cent. Also, in certain cases the pulse rate after exercise gave similar results (within the same order of difference) when the exercise was repeated on the same subject under identical conditions, after a period of rest.

3. RESTING PULSE RATE AND OTHER FACTORS

The mean pulse rate at rest, mean total number of beats in the two minutes after exercise, mean pulse rate for the first half-minute after exercise, and mean pulse ratio are shown in Table 3, which also contains the mean number of steps taken and the work done in stepping, computed in foot-pounds. As there is no apparent difference between the results for boys and those for girls, consideration of the two together appears justified.

The correlations of the pulse ratio with some of the factors involved in the tests are given in Table 4. The coefficient of correlation between resting pulse

rate and the maximum pulse rate in the first half-minute after the exercise was $r = + 0.384 \pm 0.081$.

TABLE 3

Pulse-rate, pulse-ratio and work done

	Sex	Number	Mean	S.D.
Resting Pulse Rate	Boys	63	84.39 ± 0.87	10.14 ± 0.62
	Girls	62	89.42 ± 1.13	13.10 ± 0.79
	Girls & boys	122	85.78 ± 0.71	11.63 ± 0.52
Pulse ½ min. after exercise	Boys & girls	71	130.0 ± 1.71	21.37 ± 1.22
Pulse ratio	Boys	60	2.468 ± 0.023	.260 ± 0.016
	Girls	60	2.473 ± 0.025	.248 ± 0.018
	Boys & girls	122	2.426 ± 0.016	.278 ± 0.012
Total pulse 2 min. after exercise	Boys & girls	122	206.6 ± 0.016	29.32 ± 1.28
No. of steps taken	Boys & girls	122	33.53 ± 0.22	3.55 ± 0.15
Work Done (foot lb. per min.)	Boys	60	2813 ± 52	602 ± 37
	Girls	59	2850 ± 47	532 ± 33

TABLE 4

Correlations of pulse ratio

Correlation of pulse ratio with:	Correl. coeff. (r)	No. of cases
Resting pulse rate	−0.239 ± 0.061	122
Total pulse 2 min. after exercise	+0.509 ± 0.061	122
No. of steps taken	+0.309 ± 0.061	122
Work done in ft. lb. per min.		
(Boys)	+0.181 ± 0.087	60
(Girls)	+0.385 ± 0.088	59

4. DECELERATION OF PULSE RATE AFTER EXERCISE

Table 5 shows the mean pulse rate per minute relative to the resting pulse rate during each half-minute of the two-minute period after exercise for girls and boys together, as there is no significant difference between them. It also shows resting pulse rate and pulse ratio divided by two for comparative purposes. Narrowing of the range of distribution is seen, as the pulse rate returns to normal. The difference in the mean pulse rate after exercise relative to resting rates in the 90-second ($P1\frac{1}{2}$) and 120-second (P.2) groups is of a lower statistical significance (four times its P. E.) than the other differences.

There is a relatively high correlation between the pulse ratio and the mean pulse rate after the first half minute, relative to resting ($P\frac{1}{2}$) $- r = +0.671 \pm 0.08$ and the same correlation exists between the total two-minute pulse beats and the maximum rate developed half a minute after the exercise. The pulse rate returned to "normal" within two minutes or less, since the difference between the 90- and 120-second groups is so small.

In counting the pulse after the exercise a marked "Step effect" was noticed in most cases to occur about 25–45 seconds after cessation of effort. The pulse from beating at a regular rapid rate suddenly fell to a slower rate from which it returned gradually towards the resting value.

There is no correlation of pulse ratio and age over the range tested, nor is a relationship to I.Q. demonstrable (Table 6). For Forms I the mean I.Q., measured by the Otis Intermediate test, was 99.6 ± 0.9, and for the Forms II, measured by the Otis Higher test, 98.7 ± 1.0. Nor is there a relationship between pulse ratio and absence from school. There is, however, a significant correlation (5½ times P.E.) between pulse ratio and scholastic achievement as assessed by school reports (Table 6).

The relationship between pulse ratio and surface area is shown in Table 7. If 25 over- or under-weight children are eliminated, the mean surface area of the remaining 97 is 1.318 sq. m. ±0.097 (S.D. 0.143) and the mean pulse ratio is 2.415 ± 0.017 (S.D. 0.246). The relationship between these two is not significantly altered.

TABLE 5

Deceleration of pulse after exercise

	No.	Mean	Std. deviation	Coeff. of var.
Resting pulse	122	85.78 ± 0.71	11.63 ± 0.52	13.6
	70	86.87 ± 0.93	11.69 ± 0.66	13.5
Pulse relative to resting 30 sec. after exercise (P½)	70	1.542 ± 0.029	0.245 ± 0.027	15.9
60 secs. after ex. (P1)	67	1.236 ± 0.019	0.227 ± 0.014	18.3
90 secs. after ex. (P1½)	65	1.060 ± 0.015	0.182 ± 0.011	17.2
120 secs. after ex. (P2)	70	0.959 ± 0.013	0.157 ± 0.009	15.2
½ Pulse ratio	70	1.206 ± 0.011	0.138 ± 0.008	11.4
(All cases)	122	1.215 ± 0.009	0.139 ± 0.006	11.5

TABLE 6

Scholastic achievement and pulse ratio

Correlation of pulse-ratio with:	r	No. of cases
Age	r = 0	120
I.Q. (first forms)	r = .01 ± .09	59
I.Q. (second forms)	r = +.266 ± .09	53
Scholastic achievement	r = +.345 ± .06	120

TABLE 7

Mean pulse-ratio for surface area groups

Surface-area group (*sq.m.*)	No. of cases	Pulse-ratio	
		Mean	S.D.
1.1	14	2.39 ± .05	.275 ± .03
1.2	23	2.29 ± .05	.317 ± .03
1.3	38	2.41 ± .02	.275 ± .02
1.4	27	2.46 ± .03	.236 ± .02
1.5	10	2.52 ± .07	.371 ± .05
1.6	6	2.55 ± .08	.283 ± .06
TOTAL	118 (96% of all cases)	2.41 ± .017	

NOTE: There were 3 cases in the 1.9 sq.m. surface area group and 1 in the 1.0 group.

Discussion

THE SUBJECTS AND TEST

The children in this study are essentially normal; the wide range of measurements emphasizes the variations consistent with good health; their physical measurements and health records show, in comparison with figures available for other countries, that nutrition and health are good, although two-thirds of their fathers are manual workers.

Although Miller and Elbel (26) recommend an optimum of 24 steps for step-up tests, in our results the pulse ratio showed only a slight relationship to the number of steps taken (Tables 3 and 4); nor was there any relationship to the work done (Table 4). However, we consider that the more reliable figures are obtained with a larger number of steps, as this eliminates factors other than the exercise that might affect the pulse-rate. This also coincides with the findings of Morehouse and Tuttle (27) that the reliability increases with the number of steps to a maximum level.

Two chief factors reflect the physiological condition in pulse-rate tests:

(1) The maximum pulse rate after exercise, and

(2) The rate of deceleration of the pulse, as discussed by Bramwell (3), Stine (30), and Abrahams (1).

(1). The pulse rate in the 30 seconds immediately after exercise is a valid measure of the maximum pulse rate attained during the exercise. The pulse ratio correlates highly with the $P\frac{1}{2}$ (pulse rate relative to resting in the first half-minute after exercise). From this it is seen that the total beats for two minutes after exercise will also correlate well with the maximum rate developed. We consider therefore that the pulse ratio is a valid measure of the maximum pulse rate attained, and this observation agrees closely with those of Brouha and Heath (4) and Hill, Magee, and Major (16). However, Gallagher and Brouha (13) object to the inclusion of the common factor of resting pulse rate on the grounds of its general unreliability. Our results indicate that the range of resting pulse rates is no greater than the range of any of the other pulse variables (Table 5). If care is taken to ensure a steady pulse before exercise, then confidence can be placed in the reliability of the results. In this case they agreed well with published figures for resting pulse rates for the age-groups investigated. Hill, Magee, and Major (16) pointed out that by dividing by the resting pulse rate a smaller range is obtained than if the total two-minute beats alone were taken as an index. This is shown to be the case in our results.

While the use of the two-minute total pulse alone may be quite valid we feel that the use of the ratio gives a clearer picture of the changes that have taken place and may also enable a narrower range of normality to be defined.[6]

(2) The pulse ratio covering the period two minutes after exercise also provides a measure of deceleration rate because the total number of beats will clearly decrease with rapid deceleration and increase if deceleration is delayed. The pulse rate has been shown to return to pre-exercise level within two minutes in almost every case. Furthermore, from Table 5 it can be seen that as the pulse rate approaches normal the range of distribution decreases until at the end of

two minutes it is almost the same as the resting distribution. The pulse ratio therefore gives a narrower range of spread than any of the half-minute readings and allows more readily the "normal" limits to be defined. Gallagher and Brouha (12) have used a similar method to measure deceleration but differ in that they count the pulse rate by doubling the pulse readings for alternate half-minutes; and also they record the readings for three minutes after exercise. This, we consider, introduces an extra avoidable counting error and is unnecessarily prolonged because normal pulses will have returned to resting levels within two minutes, and abnormal ones will be detected within that time.

The "step" phenomenon occurring during deceleration appears to have no obvious physiological explanation. There are no significant differences for any of the measurements except the physical, between boys and girls; here the girls were slightly taller and heavier than the boys. This is usual in this age-group.

School attendance is probably not a good measure of the health of the children although it has been shown to run parallel to respiratory infections (Galloway and Gunn, (14). Such infections are usually short and leave little debility; they would not be expected to interfere with the tests unless they were carried out in the course of the illness. None of the children had a health history of anything that might make them permanently unfit.

CORRELATIONS

The absence of correlation between pulse ratio and I.Q. is not unexpected and parallels the findings of Giaque (15) and Ilsley (17.) The relatively high correlation between pulse ratio and scholastic achievement is rather surprising. It would appear to show that the less fit people do better at school. This is particularly interesting in view of the suggestion of Douglas (11) that schoolwork and health run parallel, and in the light of the idea of "overall fitness" put forth in the introduction and by Kessler (20). It is regrettable that there could be no practicable controlled measure of the amount of physical activity of the children without involving more time than was available; such a measure would be difficult to make objectively.

Following Gallagher and Brouha (12) and Johnson, Brouha and Gallagher (18), pulse ratios were related to surface area groups, though the groups are in a smaller range than these workers, who investigated older people. There appeared to be some relationship between surface area and pulse ratio and it may be that there is a "normal" pulse for each group. However, owing to the small numbers involved the deviation is wide and 96 per cent of cases fall within one S.D. on either side of the mean for the whole series. With larger numbers the S.D. would be less and it would be possible to prove statistically whether or not there is really a relationship.

DEFINING A "NORMAL" RANGE

With the numbers used in this investigation the range of normal appears so wide that it is difficult to define its limits. Indeed, Hill, Magee, and Major (16), working with only 70 cases, considered that there was no such thing as a

normal response of the pulse to exercise for a group. On the other hand, workers experienced in the use of step-up tests are of the opinion that responses can be graded and classified. Cureton (9), using the treadmill as the standard exercise, publishes the following figures for pulse ratios: Excellent 1.5–1.7; Very Good 1.8–2.0; Good 2.1–2.3; Average 2.4–2.5; Under Average 2.6–2.8; Poor 2.9–3.1; Very Poor 3.2–3.4. This average value of 2.41 with an S.D. of 0.29 compares very closely with our mean value of 2.43 with an S.D. of 0.28.

Even if the range of normality for a group is wide, the pulse ratio of any individual is considered to be fairly constant in health. Retest results of Hill, Magee, and Major (16) and of Gallagher and Brouha (13) have shown this to be the case. In this investigation, random cases whose results were checked showed good uniformity. Sievers (29) used step-up tests for testing cardiac function and detecting abnormalities. School medical officers in New Zealand use their own subjective tests of fitness, with no advised standardized procedure. Dawson (10) recommends pulse ratio tests as a preliminary "screen" and prediction of fitness, to be followed by a full examination.

Summary and Conclusions

1. A hypothesis of "physical fitness" as a socio-economic concept has been put forward. The use of physical fitness tests as a measure of the physiological component of general fitness has been discussed.

2. Step-up tests of cardio-vascular fitness as discussed and used in this study may be applied economically to large-scale investigation. The test is probably as useful and valid as any other of this type of test commonly used. It is recommended that the "Procedure" outlined in this article be adopted as standard. This test takes four minutes per subject to perform and is conveniently administered by one operator, with minimal equipment and skill beyond practice in counting pulses.

3. Such a step-up test of physical fitness has been applied to 122 normal New Zealand schoolchildren and the results correlated with I.Q., scholastic achievement, school attendance, and surface area. Results are also reviewed in relation to similar work by other authors.

4. The range of normal with the relatively small number of cases is so wide that many of the results appear of questionable significance, in the absence of figures for the same test from other workers, and in the absence of "abnormals" for comparison. The results obtained do agree closely with those of most other workers whose work has become available. A normal mean "pulse ratio" (pulse rate for two minutes after exercise divided by the normal resting rate) of 2.426 ± 0.016, with a standard deviation of 0.275 found, is in close agreement with what other figures there are available for similar tests.

5. The test may be of value as an adjunct to physical education and health or athletic programs, or to medical examination.

Acknowledgments

We wish to thank Mr. D. Forsyth, Mr. A. J. Southgate, and the staff of the Dunedin North Intermediate School; Miss O'Connell of the Health Clinic; and

Professor J. C. Eccles for their generous co-operation. We are grateful to Mr. P. A. Smithells for making available his library, including the RESEARCH QUARTERLY, the only complete set in New Zealand; to Dr. R. Hunt for his assistance in collecting data; and also to Mr. D. R. Wills of the Physical Education branch of the Education Department for his interest and encouragement.

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The Velocity Curve of Sprint Running

With Some Observations on the Muscle Viscosity Factor

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Proceeding under the assumption that the net force determining the speed of a sprint runner represents a balance between a constant propelling force and a resistive counter-force owing to the "viscosity" of the muscles involved, A. V. Hill and colleagues in 1927 derived an equation that seemed to describe rather accurately the sprint velocity curve. This "viscosity" concept seemed very reasonable at the time, since it accounted so nicely for such experimental facts as that the oxygen requirement of running increases approximately as the cube of the speed and that the metabolic efficiency of standardized work (such as exercise on the bicycle ergometer) drops off tremendously at fast rates of movement (8).

Fenn refused to accept this concept (2), his most convincing argument against it being that experiments on isolated muscles proved that limitation of the speed of movement was due, not to viscosity, but rather to a "tension loss" factor resulting from the finite rate of energy release in the biochemical process (3). Consequently, Hill did further work on amphibian muscle, and, while disagreeing with some of the details of Fenn's theoretical position, accepted the idea that "viscosity", while present, was quantitatively unimportant as a limiter of the speed of muscle movement (9). Since 1938 there seems to have been agreement in the research literature that the viscosity concept as an explanation of the limitation of muscle performance at high speeds of movement is outmoded. Nevertheless, the concept still persists in physical education literature.

Now, quite regardless of whether or not the viscosity idea must be discarded, Hill's formula for sprint running deserves further consideration. For velocity, it takes the form

$$\frac{dy}{dt} = v_m (1 - e^{-kt}) \tag{1}$$

which states that the speed of the runner at any time t approaches a limiting velocity v_m according to an exponential law, the rate of approach being determined by the reaction velocity constant k (not to be confused with the runner's own velocity). While this formula may be derived as was done by Hill, postulating that the runner's forward motion is opposed by a counter force that is proportional to his speed at any time t, this latter force could be the result of tension of antagonistic muscles and other kinesiological factors (2). Or it might not be a true force at all, but simply the force-equivalent of some biochemical or circulatory limiting factor.

Hill and his colleagues never really established that the mathematical expression truely described the data. His statement for instance that "no better agreement could be expected" between theory and experiment than he found in the case he selected for detailed presentation (8, *p. 56*), is quite typical of the informal statistical methods in use at that time. Present-day practice requires that due respect be accorded to sampling theory and the probability laws, before proof of agreement can be claimed. Similarly, the presentation in brief case reports of the curve constants and time scores of a few individuals who run exceptionally fast and have a low "viscosity constant" (1; 8, *p. 71*) cannot be claimed to have established individual differences in the curve constants or in the relation between the "viscosity" constant and running ability.

The present investigation is therefore concerned with such questions as:

(a) Does the exponential formula truly describe the time-velocity curve of a sprint runner?

(b) Are there individual differences in the curve constants, and if so, how consistent are they?

(c) What is the relative importance of each of the curve constants in determining the speed of a sprint run?

(d) Is Hill's viscosity constant related to metabolic efficiency in fast-movement work in human subjects?

(e) What is the role of the curve constant k?

Methodology

The timing device was unlike the one used by Hill, which recorded the current induced in a galvanometer by a magnet carried past the timing stations by the runner. Instead, the runner momentarily broke an electric circuit by body contact with each member of a series of light bamboo sticks, one of them projecting across the track at each timing station. Each stick was supported by a special hinge that carried a contact, also a catch that held the hinge open and inoperative after each action. As the runner ran down the track and passed each stick he contacted it with his body midway between knee and elbow. This caused the "gate" to swing open, momentarily opening and then re-closing the electric circuit, with a resultant mark by a recording pen on the chronograph. With this arrangement, the 10 gates used in timing the 50-yard runs of the present experiment could be placed in series so that they all recorded by a single pen. Also in series was a clap-board that carried electric contacts to automatically mark the starting signal.

The chronograph, made from a constant speed phonograph motor, moved adding-machine tape past the recording pen at the rate of 3.4 in/sec. Another pen was actuated by the teeth of a 50-tooth gear turned by a telechron motor revolving at 1 r.p.s., recording peaks and valleys separated by 0.01 sec., making it possible to measure time by interpolation with an accuracy somewhat better than 0.005 sec. Every fifth tooth was partly filed down, and one tooth was built up, so that distinctive marks appeared on the record at tenths of seconds and one second. This convenience greatly facilitated the reading of the chronograph tape.

Two additional pens on the chronograph were coupled mechanically to the starting blocks, which were mounted on roller bearings and backed by stiff

springs so that there was a movement of approximately a quarter inch when the runner exerted his full force against them. The coupling system magnified this movement fourfold. This set-up was designed for the purpose of studying the time-force characteristics of the take-off of the runner from the blocks. That, however, is another problem which will be reported on separately. In the present investigation, the device was used to determine *zero time*, defined as the instant that the runner first began to exert force against the blocks in response to the starting signal. Thus, *reaction time*, defined as the period between the starting signal and the beginning of muscular movement, is not included in the time scores as reported.

The longitudinal spacing of the blocks was 18 inches, which has been found in this laboratory to be near the optimal for most runners (5). The runner was permitted to use either foot forward, according tc his individual predilection. Tennis shoes were worn. The black-top surface of the track was quite rough-grained, so there was no trouble with slippage. Timing stations were placed at 5-yard intervals, with a 20-yard pull-up space beyond the 50-yard mark.

Continuous oxygen consumption measurements during during exercise and recovery were made while the subjects rode an electric bicycle ergometer at the near-optimum pedal speed of 69 r.p.m. at a work load of 615 kg.m/min. and a fast-movement speed of 113 r.p.m. with a load that had the same metabolic cost. Details of the apparatus and method used for these metabolic measurements have been given in other papers (6, 7).

Data were secured on 25 young men, student in the physical education major curriculum. Their height averaged 5.9 feet, ranging from 5.6 to 6.3 feet, and their weight averaged 176.5 pounds, ranging from 145 to 230 pounds. Ages were from 22 to 26 years, except for 2 men who were 30 and 31. All were physically active, of course, but none was an experienced track man. After a numbei of practice starts, a few sub-maximal trial runs were made to secure an adequate warm-up and familiarize the men with the starting gates. They very quickly adapted to the situation, reporting that the gates were usually not noticed during the run. Then two runs were made, separated by a 15-minute rest. Apparently this was adequate, since the mean time of the second run was less than 0.01 seconds slower than the first.

Because the first 15 yards of a sprint run involves a rapidly changing speed, it was not possible to determine the velocity at the first few stations with the required precision. For this reason, the integral form of the equation of motion

$$y = v_m\left(t + \frac{1}{k}e^{-kt} - \frac{1}{k}\right) \quad (2)$$

was used. In this formula, y is the distance attained by the runner at any time t, the nomenclature being in other respects the same as in the first equation. Algebraicly, this formula is the same as the one used by Hill.[1] It is of interest

[1] Hereafter the symbol v_m, representing the asymptotic (maximum) velocity of the runner, will be more simply denoted as v. It should be mentioned that this is the equivalent of Hill's term fga. The symbol k is the equivalent of Hill's $1/a$, which is the reciprocal of his "viscosity" constant.

that the acceleration of the runner, i.e., the rate of change in volocity, is the second derivative of formula **2**, *viz.*:

$$\frac{d^2y}{dt^2} = kv_m\, e^{-kt} \tag{3}$$

Experimental Results

Velocity and acceleration curves. These are shown in Figure 1. The basic prediction is the distance y attained by the runner at time t according to formula **2**. The course of events is more readily visualized from the velocity curve dy/dt (from formula **1**) and the acceleration curve d^2y/dt^2 (from formula **3**). No experimentally observed points have been plotted for the first few timing stations, except for y, because the rapidly changing speed would make them meaningless unless the timing station intervals had been much closer together than 5 yards. It can be seen from these curves that most of the acceleration occurs quite early in the dash—90 per cent of the maximum velocity is reached by 15 yards, and 95 per cent by 22 yards. It should be mentioned that velocity and acceleration are not exponential when plotted as in Figure 1, because the abscissa used is *distance.* Plotted against time, they yield exponential curves.

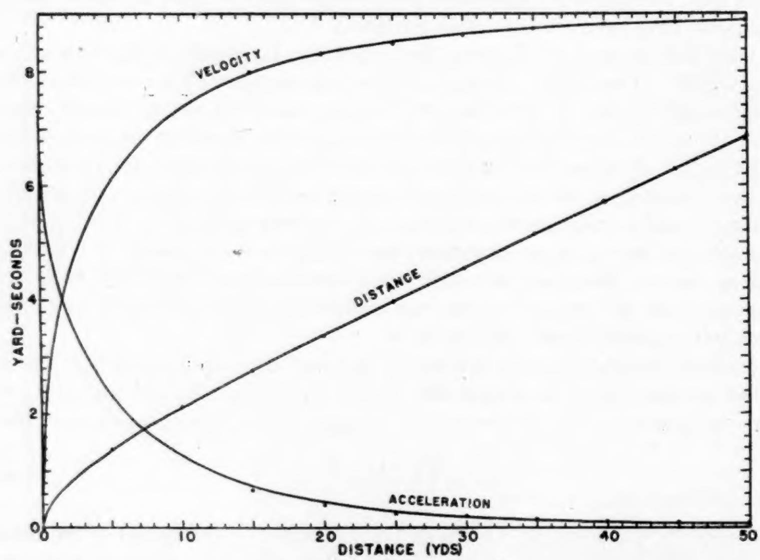

FIG. 1. Theoretical Curves and Experimental Observations. The ordinate is to be interpreted as *time in seconds* for curve y (distance), as *yards per second* for curve dy/dt (velocity), and as *yards per second* for curve d^2y/dt^2 (acceleration).

Since force is the product of *mass* and *acceleration* (according to physics), the acceleration curve can be converted to net force exerted by the runner over and above that used to overcome internal or external resistances. The average weight of the subjects W was 176.5 pounds. This is not mass, but the force exerted by gravity on the runners mass, so it must be divided by 32 to convert it to *slugs*; also yards must be converted into feet to correspond to the gravitation units. The net force f available for acceleration at any time t is therefore

$$f = \frac{3}{32} W(kve^{-kt}) \tag{4}$$

By substituting the term $(1 - e^{-kt})$ for e^{-kt}, this formula gives the *loss* in effective force, although it makes no differentiation between loss due to the building up of counter-forces and muscle tension loss as such.

At $t = 0$, just as the runner leaves the blocks, the calculated external mean force turns out to be 121 lb., with $\sigma = 14.9$ lb. and the test-retest reliability $r = 0.93$. The magnitude of this force is in remarkably close agreement with the figure of 130 lb. that was acually measured at the start of forward movement in another group of subjects (5). The latter group included a number of experienced runners who ran considerably faster than the present group, so their initial force would be expected to be somewhat larger.

Confirmation of the formula. In order to determine if there is statistical agreement between the formula and the experimental results, individual curves were fitted for each run by the trial and error method. Advantage was taken of the fact that in the region of 40 yards, the velocity of the runner is very close to the asymptotic value so that the term e^{-kt} has a magnitude of about 0.01 and can be neglected for the first approximation. Hence we may write

$$k = \frac{1}{t - \frac{y'}{v}} \tag{5}$$

Where y' is the distance where the observation takes place (e.g., 40 yds.), t is the time required by the runner to go this distiance, v is the observed velocity at y' (which can be easily computed from the time required to go from 35 to 45 yd., or wherever the maximum velocity occurs), and the term y'/v is the time that would have been required for the 40 yards if the entire distance had been run at the velocity v. Using the tentative values of k and v calculated by this method, one or two comparisons were made using formula **2** and the curve constants adjusted to improve the fit by inspection. No doubt a better fit would have been secured by using the least squares method, but with 50 curves to be fitted, the labor involved would have been impractically large.

Using the final values of k and v, the discrepancies (errors) between the calculated and observed distances were determined for each timing station. The errors for each man's two curves were averaged and used to determine the statistical significance of the error of the mean (in terms of distance) for the 25 subects at each timing station, using the "t" ratio method. The results are shown

in Table 1. It will be seen that the cumulated mean error for the 10 timing stations is 0.086 yds., which averages to 0.030 yds. or approximately one inch per station if the direction of the error at each station is neglected. There is a tendency for the runners to be somewhat slower than predicted by the formula in the first 15 yards and faster in the region of 20–25 yards. This may represent a chance variation, or it may reflect the observed fact that the track was not a true plane surface, being downhill to the extent of several inches in the first 15 yards and then uphill to 30 yards. At the 20-yard station the error is greater than would be expected by random sampling theory, since the calculated probability is only $p = 0.02$. While it is true that "statistically significant" differences are occasionally found in a series of critical ratios in the absence of any systematic cause (as is indeed implied by the calculated probabilities), the nature of the imperfection of the track furnishes an adequate explanation of the slight deviation from the formula in the present case.

TABLE 1

Statistical summary of calculated and observed performance

(Predicted distance computed from mean time, using $k = 0.820$ and $v = 8.90$ yds/sec.; error computed from individual times and curve constants)

Distance	5 yd.	10 yd.	15 yd.	20 yd.	25 yd.	30 yd.	35 yd.	40 yd.	45 yd.	50 yd.
Predicted (yd.).....	5.04	10.02	15.12	19.89	24.96	29.97	35.02	40.03	45.00	49.90
Mean error (yd.).....	0.046	0.052	0.042	−0.064	−0.016	−0.005	0.023	0.021	−0.003	0.010
σ_M error....	0.025	0.026	0.022	0.025	0.020	0.019	0.017	0.019	0.024	0.030
Critical ratio ("t")	1.84	2.00	1.91	2.56	0.80	0.26	1.35	1.11	0.13	0.33
Mean time (sec.)....	1.40	2.14	2.78	3.38	3.98	4.56	5.14	5.70	6.27	6.83
σ (Single runs).....	0.067	0.088	—	0.136	—	0.176	—	—	—	0.293
Reliability (r).......	0.806	0.914	—	0.952	—	0.956	—	—	—	0.919

Intercorrelation of errors. As a matter of minor interest, a correlation coefficent was computed between each subject's deviation from the formula in each of the two runs at the 5 yd. station. It turned out to be $r = 0.44$, which is statistically significant at the 4-per cent level of confidence. This is a rather small correlation, and is interpreted to mean that while there is a slight tendency for individual runners to depart from the formula in an individually characteristic manner, most of the error variance is completely random in nature. At the 50-yard station, the errors in the two runs show no significant intercorrelation, since $r = 0.12$.

Correlation between predicted and observed time. A correlation coefficient relating observed and computed distances would be meaningless, since each of the timing stations was at constant distance, and the correlation between a constant and a variable is necessarily zero. It would be possible to determine

each runner's position at a fixed time by interpolation and then correlate the observed and computed distances, but this would in effect be averaging more than one observation. On the other hand, the time scores cannot be predicted by the formula, since an expression of this form cannot be solved for t. The best compromise appeared to be the conversion of each distance error, Δy, into an equivalent Δt, by means of the computed velocity $dy/dt = v$ calculated for each timing station, using the formula

$$\Delta t = \frac{\Delta y}{v} \tag{6}$$

This procedure involves the assumption that $\Delta y/\Delta t = dy/dt$, which is reasonable because the increments, while not infinitesimal, are very small—of the order of 0.1 yard and 0.01 second.

The correlations, therefore, related t and $t + \Delta t$. They were computed for the two runs separately, at the distances 10, 20, and 30 yards. All the coefficients were very high, ranging between $r = 0.98$ and $r = 0.99$. A note of caution should be introduced at this point—these results do not exactly mean that the formula holds with this degree of reliability; rather, they imply that individuals who are relatively fast or slow by direct observation at a particular timing station are almost certain to be relatively fast or slow with respect to their position on the track as calculated by the formula, using individual values of the two parameters k and v.

Individual differences in curve constants. The term *individual differences* is frequently used but almost never defined; consequently, its implications are often misconstrued. Consider a situation where all individuals have the same *true score* in some function, but the *observed scores* differ by superimposed random factors. Individual scores will therefore differ, even though there are by definition no individual differences in the function. It is therefore necessary to retest the individuals and make some sort of statistical analysis that compares the real individual differences to the random differences. In the ideal situation, the variability of observed scores will be the same in both the original test and the retest, i.e., $\sigma_I^2 = \sigma_{II}^2 = \sigma_x^2$, the *observed* variance. Using σ_T^2 to denote *true-score* variance and σ_e^2 for *error* variance, it can be shown that the formula for the reliability coefficient can be written in several ways that justify its use as a measure of the extent that individual differences are present in the function being tested:

$$r = \frac{\sigma_T^2}{\sigma_x^2} = 1 - \frac{\sigma_e^2}{\sigma_x^2} = 1 - \frac{\sigma_{I-II}^2}{\sigma_x^2} \tag{7}$$

Correction of the "raw" reliability for attentuation can be justified—the corrected coefficient, which is the *index of reliability* ($\sqrt{r}$), is interpreted as representing the correlation between *observed scores* and *true scores* in the function (12, *pp.* 468–470).

The test-retest correlation for the curve constant k is found to be $r = 0.75$, the standard deviations of the individual k's being 0.074 in run I and 0.065

in run II, with the mean $k = 0.820$. For v, the figures are $r = 0.91$, $\sigma = 0.445$ and 0.482, with mean $v = 8.90$ yd/sec. The index of reliability for k is 0.86, and for v, 0.95. Without question, there are decided individual differences in both parameters; while they appear to be somewhat more reliable in the case of v, this difference is not statistically significant as calculated by a z transformation. The k's and v's are independent measures, the intercorrelation between them being non-significant ($r = -0.28$ in the first run and -0.15 in the second). Both curve constants are normally distributed as evidenced by linear ogives when they are plotted against a probability ordinate.

Relative importance of k *and* v *in determining time scores.* For this analysis, the data of the two runs have been handled separately so that the findings of the two experiments (performed on the same individuals) can be compared. Results of the correlational analysis are shown in Table 2. It will be seen that the multiple R's relating k and v to observed running time are definitely smaller than the r's between running time and the time predicted from k and v by the exponential equation. The explanation is of course that R is obtained, in effect, by adding the variances of k and v linearly, whereas k is an exponent. Nevertheless the R's are quite large when visualized as validity coefficients, thus justifying the treatment of individual k's and v's simply as scores that measure the relative status of each individual with respect to the two important factors that determine how far he can run in a specified time.

TABLE 2

Intercorrelations between time scores t and curve constants k and v

Distance		5 yd.	10 yd.	20 yd.	30 yd.	50 yd.
$R_{t(kv)}$	I	0.860	0.925	0.952	0.962	0.960
	II	0.924	0.948	0.962	0.963	0.950
r_{tk}	I	−0.706	−0.540	−0.326	−0.217	−0.084
	II	−0.631	−0.556	−0.389	−0.262	+0.156
r_{tv}	I	−0.343	−0.634	−0.811	−0.868	−0.907
	II	−0.614	−0.713	−0.839	−0.901	−0.937
r^2_{tk}	(avg.)	0.448	0.301	0.129	0.058	0.016
r^2_{tv}	(avg.)	0.248	0.455	0.682	0.784	0.851
β^2_k	(avg.)	0.653	0.469	0.319	0.207	0.067
β^2_v	(avg.)	0.435	0.695	0.901	0.969	0.948

Detailed inspection of Table 2 reveals that, although significantly related to the running time at the 5-yard and 10-yard stations, k exhibits regularly decreasing correlations that drop to approximately zero at 50 yards. This means, unequivocally, that individuals with a large k or a small k are equally likely to be good 50-yard sprint runners. On the other hand, v is the most important determiner of sprinting ability from 10 yards on, and the *only* important determiner for distances of more than 20 yards. This is most clearly shown for the figures for r^2, which (when multiplied by 100) represent the percentage determination of variance in sprint time by k or v as the case may be. The β coefficients are also shown in the table; they are perhaps not as well suited to the present purpose as the r^2's since they neglect the "joint contribution" term $2\beta_k\beta_v r_{kv}$. However, both methods lead to the same conclusion.

Relation of "viscosity" to metabolic efficiency of work. The "viscosity" concept implies that there is a fundamental characteristic in the muscle that makes it inefficient at fast rates of movement because energy is expended to overcome the resistance of the muscle to changes in shape or length. Since approximately the same leg muscles are used in cycling and running, this concept predicts that individuals with a high (or low) muscle viscosity as determined in sprint running should have a low (or high) metabolic efficiency in working on the bicycle ergometer—i.e., they should require a relatively large (or small) amount of oxygen to do a standard amount of work.

When the average sprint run k's of the 25 subjects are correlated with their efficiencies in doing optimum speed exercise on the ergometer (averaging two determinations), the coefficient is $r = 0.08$; when correlated with fast-movement efflciency, $r = 0.22$. The correlation between k and the reduction in efficiency of fast compared with optimum work is $r = 0.02$. None of these coefficients is even close to statistical significance. This failure to confirm the prediction cannot be ascribed to low reliability of any of the measures, since the reliability of k as determined by the Spearman-Brown method is $r = 0.85$, while the corresponding reliability for optimum speed ergometer efficiency is $r = 0.72$ and for fast movement efficiency, $r = 0.84$. It follows that the "viscosity constant" is unrelated to any general factor that influences the efficiency of muscular work.

Correlation between metabolic k*'s and sprint* k*'s.* It was shown in another paper (6) that the rate that an individual oxidizes the non-lactate metabolites of exercise, during both exercise and recovery, is described by the individual k coefficient. In this case, the k is computed from the oxygen uptake curve during exercise or from the oxygen debt pay-off curve. Since these metabolic k's were available for all the subjects, they have been correlated with the sprint run k's. The resulting coefficient is $r = 0.06$ for the "optimum" rate of movement and $r = 0.003$ for the "fast" movement bicycle exercise. It is obvious that individual differences in the two kinds of k's are unrelated; in addition it may be mentioned that they are of an entirely different order of magnitude, since the k's of the sprint curve average 0.82 in seconds units whereas the metabolic k's average 0.013 in the same units. Stated in less esoteric language, the rate of attaining speed in sprint running is very high, half the maximum speed being attained in less than a second,[2] whereas the rate of attaining an increased oxygen supply to the muscles as a result of exercise is relatively slow, requiring nearly a minute for half of the total increase to occur. It is therefore obvious that the acceleration curve of the sprint runner is not determined or limited by his use of oxygen during the run. The implications with respect to possible effects of breathing pure oxygen just before a sprint run should also be obvious.

Reaction time of the runs. Defining reaction time as the time between the starting signal and the beginning of pressure on the blocks, the mean RT was 0.133 sec. ($\sigma = 0.038$) for the first run and 0.131 sec. ($\sigma = 0.038$) for the second.

[2] The term *half-time* is frequently used to describe the time characteristics of an exponential or logarithmic process. The calculation from k is easily accomplished; $\frac{1}{2}T = 0.693/k$. If a process has a half-time of one second, half of the process will be accomplished in the first second, a fourth of it in the next second, an eighth in the next, and so on.

The test-retest reliability was $r = 0.69$, which is statistically significant at well above the 1 per cent level. It was noted that pressure was invariably started with the back foot first, with a delay that average 0.047 sec. before the front foot came into action.

Discussion

Among the 50 velocity curves that have been analyzed, there are some that show discrepancies between theory and observation that do not exceed 0.01 or 0.02 yards; there are also some that show discrepancies as large as 0.20 or 0.30 yards. From individual cases, it could be concluded that the formula either does or does not apply, depending on the bias of the interpreter. The statistical analysis shows that the observed discrepancies can mostly be accounted for by sampling error. True, there is one region at about 20 yards where the fit is not as good as might be desired, but there is a fairly good explanation for this. In justifying this explanation, it should be pointed out that the Hill data on 10 men (8, *p. 68*), when averaged and fitted with the theoretical velocity curve, show a *negative* deviation at 6 and 10 yards, where the errors of the present experiment are positive, and a *positive* deviation at 20 yards, where the present experiment shows a relatively large negative deviation. This finding further supports the sampling error hypothesis for the deviations, permitting the conclusion that the formula does indeed describe the horizontal movement of the sprint runner. Further support comes from the prediction of starting block force from the acceleration curve; this is a particularly sensitive test since it involves the *second* derivative. However, the precision of the description as applied to individuals is by no means as accurate as claimed by Hill; in fact, when *all* of his published data are inspected, it can be seen that some of his runners are as variant as those observed in the present experiment.

According to the Hill derivation, the coefficient v is in reality fg/k, where f is the constant propelling force exerted by the individual runner (in proportion to his weight) and g is the gravity constant 32 ft./sec.^{2}. Thus v would have to be proportional to f/k and would necessarily have a high negative correlation with k because of the common factor (assuming that f and k are independent as implied by the derivation). It will be recalled that, on the contrary, the correlation between v and k does not differ significantly from zero. Furthermore, the concept of "tension loss", as pointed out by Fenn (2, 3), is incompatible with the presence of a *constant* propelling force throughout the run. Even with maximum exertion, the force will drop off as the runner approaches his maximum speed, the loss of muscle tension at high speed serving to explain, at least in part, why it is that the runner is limited to a maximum velocity.

The concept that the curve constant k (Hill's viscosity constant) is important as a predictor of speed in a dash run, is disproved. There *are* individual differences in k, but their relation to speed is quantitatively important only when the distance is very short, of the order of 5 to 10 yards. Individual differences in maximum (i.e., asymptotic) speed v are quantitatively greater, and constitute the important factor that determines how fast a dash of 30 to 50

yards can be run. For lesser distances, both factors k and v are important. This result has some interesting practical consequences. In sports situations where the person makes a run of more than 30 yards (and probably up to 80 to 100 yd., although this upper limit represents a shrewd guess rather than an experimental fact) a single test yielding the measure v is adequate to predict individual differences in the speed function. In contrast, for runs of shorter distance, both k and v must enter into the prediction. Furthermore the prediction is to a considerable extent specific to the distance involved in the run. Consider two individuals, one with large k and small v, the other with small k and large v. Both may be equally fast at 10 yards, but one will be faster at 5 yards and the other at 15 yards. It follows that highly successful prediction of short distance speed will depend on using the exponential formula, or a multiple regression using the two factors with different weights depending on the distance under consideration.

The above discussion has neglected the role of reaction time in sprint running. That it is usually unimportant can easily be shown without a correlational analysis, because in the present case we are concerned with the extent to which the *time* of reaction *as such* can determine differences in the time of a run, rather than whether or not "fast reactors" are "fast runners." As shown earlier, the reaction time in the runs had a variance (σ^2) of 0.0014 sec. Assuming that the variances are additive, 24 per cent of the total time variance at 5 yards. (Table 1) will be due to reaction time, compared with 15 per cent at 10 yards, 7 per cent at 20 yards, 4 per cent at 30 yards, and less than 2 per cent at 50 yards. Furthermore, fast reactors are *not* fast runners—the reaction times only correlate $r = .14$ with 50 yards times, which agrees with the results of another experiment in which the average of 60 finger-press reactions was not significantly correlated ($r = 0.28$) with the average time on two 50-yard dashes (12, *p. 469*). A third experiment also showed no correlation (11). Contrary to popular belief, individual differences in the reaction time function can be neglected except for very short distances, perhaps 10 or 15 yards at the most.

Since the "viscosity" concept must be discarded, there still remains the problem of accounting for the individual differences in efficiency, and for the exponential curve of sprint running. It is quite possible that there is no common element relating the two. While there is no direct experimental evidence to justify the position, the high degree of task-specifity that seems to characterize efficiency (7) suggests that it is a matter of neuro-muscular skill rather than a fundamental physiological factor. A further lead in this direction comes from a correlation calculated from data presented by Slater-Hammel (13) on the rate of striding of individuals running at top speed and on the maximum rate of pedaling of the same men when riding an unloaded bicycle. While the intercorrelation, $r = 0.46$, is statistically significant, it is quite small and accounts for only 21 per cent of the variance as being common to the two activities. An experiment by Hubbard (10) also emphasizes the specific skill factor. This concept appears to be implicit in the analysis of the dynamics of motion reported by Fenn and associates (2, and later publications on the same topic). An alter-

native possibility for explaining loss of efficiency in fast movement would seem to stem from the "Fenn effect,"[3] namely that there is extra heat production when a muscle shortens, owing to the shortening, but independent of the amount of work done by the shortening (9, *p. 159*).

It is possible to derive a mathematical expression of the form of equation **1** that is based on the tension loss concept, assuming that the speed of muscle contraction is proportional to the speed of the runner and that the force of contraction is proportional to the force exerted in propelling the body. The curve constants in this expression would be visualized as representing some sort of average values considerably slower than those characteristic of individual muscle responses. It may be noted that this possibility is not unreasonable, since the k of an isolated frog muscle contraction at 20°C., calculated from data published by Hill (9, *p. 187*) is 7.7, which represents a half time of only about a tenth-second. Not much confidence can be placed on the theoretical implications of such a derivation, however, because of the probability that loss of propelling force also occurs as a result of the muscle coordination factor at high speed.

In the light of the above discussion, it seems necessary to consider equation **1** (and its corollaries) as a very general type of theoretical statement. It is a mathematical expression that is descriptive of many biological processes that include aspects of growth, oxygen consumption, inert gas or radio-isotope exchange, and so on. Since these processes are different, the derivations are different, but in each case there is some reaction that exponentially approaches an equilibrium or asymptote. The physiological significance of the curve constants, in the case of sprint running, must be elucidated by further research. It may be anticipated that detailed study of the velocity for the first few yards of the run may reveal weaknesses in the exponential formula as applied to this region, because there is very likely a transition between the horizontal jump aspect of leaving the blocks and the picking up of a normal stride. This is a minor matter. It should also be realized that even though the exponential formula fits the data within the limitations of sampling error, it is not impossible that some other mathematical expression can be found that will also meet this criterion. It must be insisted, however, that any formula proposed for the purpose must describe the data in all three aspects, namely position (integral), velocity (first deviative) and acceleration (second deviative).

The formula in its present form does not apply to distances greater than 40 or 50 yards, since the velocity decreases thereafter. Some preliminary work has indicated that the addition of a second subtractive exponential term to the formula will extend the prediction to several hundred yards, provided that the run be of the "all out" type using maximum effort in all parts of the run. The k_2 of this term is of the same order of magnitude as the k of aerobic oxidation observed during exercise (6), a finding that suggests some interesting lines of speculation concerning causal factors.

[3] Fenn himself holds that the efficiency of fast muscle movement is just as high as that of slow movement, which places the burden of loss in efficiency on the coordination factor. See p. 502 in Höber, R., *Physical Chemistry of Cells and Tissues*. Philadelphia: Blakiston (1945).

Summary and Conclusions

An automatic timing apparatus was used to determine the reaction time (on the blocks) and the speed at 5-yard intervals during a 50-yard dash. The subjects, 25 young men who were inexperienced runners, made two runs each. They also rode a bicycle ergometer twice at a pedal speed of 69 r.p.m. with a work load of 615 kg.m/min and again at 113 r.p.m. with a work load of 89 kg.m/min. During the ergometer work the oxygen consumption was measured continuously with a closed circuit metabolism apparatus.

The distance y covered by the average runner at any time t was predicted within a few inches by means of the formula $y = v\,(t + \frac{1}{k}e^{-kt} - \frac{1}{k})$ when v, the maximum velocity, was taken as 8.90 yd/sec and k, the velocity constant, was taken as 0.820 in seconds units. When individual values for v and k were determined for each man, it was demonstrated that the errors of the predicted distances were probably sampling errors. The velocity curve $dy/dt = v\,(1 - e^{-kt})$ and the acceleration curve $d^2y/dt^2 = kve^{-kt}$ also appeared to fit the experimental data satisfactorily.

Reliable individual differences were found in the individual curve constants, the test-retest reliability being $r = 0.91$ for v and $r = 0.75$ for k. These two factors were found to be independent. The correlations between individual time scores as observed and as predicted by the curve constants ranged from $r = 0.98$ to $r = 0.99$. It was found that k was an important determiner of speed for the first 5 or 10 yards, but not thereafter, whereas the curve constant v was important at all distances greater than 5 yards, and the only important factor after 20 yards. Both factors were required to predict speed for very short runs, although a single factor was sufficient for dash runs of the order of 30 to 50 yards. Reaction time was also an important factor for a 5-yard dash, but of no importance if the run was 20 yards or longer.

Metabolic efficiency was found to be uncorrelated with the so-called muscle viscosity constant $1/k$. The curve constant k describing the rate of attaining speed in running was approximately 70 times faster than the corresponding k for oxygen consumption, proving that the latter can play no part in determining the acceleration curve of sprinting.

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The Objectivity of Judging at the National Collegiate Athletic Association Gymnastic Meet

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The judging of a gymnastic meet, like the judging of diving, is essentially a composite of subjective opinions on a particular performance. In the case of a National Collegiate Athletic Association Gymnastic Meet, five judges rate each performance. The high and low scores are discarded and the middle three are summed to determine the winner of an event. The writers were interested in examining the data from the 1950 National Collegiate Athletic Association Meet held at the United States Military Academy. It was felt that the caliber of judging at this level of competition was the best available.

Procedure

The official results of the above-mentioned meet were secured on the following events: side horse, parallel bars, trampoline, horizontal bar, flying rings and tumbling. These data included the score which each of the five judges gave an entry plus the sum of the middle three scores for each contestant and finally the order of placement of the performers.

The intercorrelations of the five judges were determined for all six events. The number of times a judge scored men high or low was also tallied in an effort to determine whether a particular judge was habitually high or low. There was some duplication here in that occasionally two judges would have the same low or high score. In these instances both were credited with an "extreme." The basic data were re-scored using the sum of the points awarded by the five judges rather than the middle three. The placement of the first six men in each event was compared with placement under the traditional system.

Results

An examination of Table 1 reveals that the judges agreed with one another to an acceptable degree. There is only one correlation below 0.800 and there are 50 relationships of 0.850 or higher. The remaining nine objectivity coefficients fall between 0.800 and 0.849. The consistency of the judges would probably compare favorably with subjective opinions of five experts rating any other physical or motor trait.

The greatest amount of agreement was reached in the judging of the horizontal bar where all correlations were above 0.880 and nine out of ten were 0.924 or higher. The judging of tumbling seems to be the weakest from a standpoint of objectivity.

Table 2 gives a summary of the number of times a particular judge's rating was high or low. If one were to look at the total number of times a particular judge scored high or low no one judge would stand out from the other four.

TABLE 1

Intercorrelations of the scoring of the five judges at the National Collegiate Athletic Association Gymnastic Meet

Judges	Side horse	Parallel bars	Trampoline	Horizontal bar	Flying rings	Tumbling
1-2	0.950	0.866	0.882	0.952	0.824	0.933
1-3	0.950	0.855	0.832	0.949	0.884	0.805
1-4	0.916	0.809	0.893	0.933	0.874	0.861
1-5	0.891	0.874	0.880	0.975	0.845	0.948
2-3	0.941	0.900	0.936	0.935	0.893	0.800
2-4	0.893	0.807	0.882	0.924	0.865	0.820
2-5	0.877	0.888	0.922	0.977	0.905	0.915
3-4	0.893	0.885	0.842	0.880	0.867	0.777
3-5	0.870	0.922	0.900	0.944	0.892	0.862
4-5	0.964	0.889	0.867	0.950	0.920	0.877

TABLE 2

Number of extreme scores for the various judges

Event	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5
Low scores					
Side horse	6	15	8	4	7
Parallel bars	5	8	2	4	10
Trampoline	1	1	2	4	10
Horizontal bar	5	8	4	7	3
Flying rings	4	7	3	14	7
Tumbling	2	2	3	10	2
Total	23	41	22	43	39
High scores					
Side horse	12	3	5	6	6
Parallel bars	6	3	11	5	5
Trampoline	7	3	5	3	0
Horizontal bar	4	2	7	5	6
Flying rings	8	4	10	3	10
Tumbling	5	7	6	1	4
Totals	42	22	44	23	31

The writers were curious to know whether using the sum of the five judges' ratings would alter the final standings in each event. The first six places were considered as these are the only ones which contribute points toward the team title. Table 3 gives a summary form of the results using both the conventional system of scoring and the five judge scheme. Definite changes in the placing of the contestants do occur. In the case of the side horse, the tie for second place

TABLE 3

Comparison of first six places using the sum of the scores of the middle three judges and the sum of the scores of five judges

Side horse			Parallel bars		
Place	3 judges	5 judges	Place	3 judges	5 judges
1	17*	17	1	21	21
2	19 and 11	11	2	23	23
3		19	3	20 and 22	20 and 22
4	26	26	4		
5	20	20	5	18	18
6	25	22	6	4	4
Trampoline			**Horizontal bar**		
Place	3 judges	5 judges	Place	3 judges	5 judges
1	12	12	1	14	14
2	7	7	2	10–13 and 18	18
3	15	15	3		10
4	8	8	4		13
5	4	4	5	15	15
6	2	2	6	19	19
Flying rings			**Tumbling**		
Place	3 judges	5 judges	Place	3 judges	5 judges
1	26	26	1	2	2
2	25	25	2	7	7
3	18	23	3	17	17
4	23	29	4	18	18
5	29	18	5	12	15
6	9	9	6	15	12

* The numbers refer to the contestant's number.

between Contestants 11 and 19 is eliminated and Number 11 takes second place with Number 19 going into third. Along with this shift, Contestant 25 dropped to seventh place and Number 22 moved up into sixth. The final standings in the parallel bars and the trampoline remain unchanged. Using the five judge system, a three-way tie for second place on the horizontal bar is avoided. Several changes takes place in the standings on the flying rings. The following shifts in position would have taken place in the placings if a five-judge system had been employed: the third place winner would have dropped to fifth; fourth place would have gone to second and the fifth place man would have finished in fourth position. In the remaining event, tumbling, the fifth and sixth place men would have changed positions.

Discussion

This study was primarily exploratory in nature and several problems have arisen which might prove to be fruitful channels for future research. The idea of employing five judges to score an event and then discarding the extremes is

challenged. Since the judges are purported to be experts it appears to be irrational to ignore the ratings of two because they happen to be high and low. If the coaches feel that they should have five judges at a particular meet they should respect their opinions and use all five in determining a winner. There is another possibility and that is that three judges may be adequate to judge the event. In most dual meets three judges apparently suffice!

Under the present system of judging at a national meet all five judges work the six events. Someone may question whether the judges are equally competent and interested in all events. Perhaps it would be wise to limit the men to the events which they are best qualified to judge. The individual's experiences and preferences might be considered as qualifications.

Gymnastic coaches will occasionally voice objections to the judging at a meet. There may be some grounds for these objections and further studies should be projected so that a more complete analysis of the objectivity of judging could be carried out. In the case of dual meets studies could be designed to determine whether or not the judges tend to favor the home team. It might prove worthwhile to examine the judging records of a number of the recognized officials over a longer period of time in an attempt to learn whether a judge is consistently low or high in a particular event. Further analysis could be carried out by use of a questionnaire. With this tool it would be possible to survey the opinions of judges and determine the items of agreement as well as disagreement.

Summary

An analysis of the judging at the 1950 National Collegiate Athletic Association Gymnastic Meet was made. The objectivity coefficients were found to be reasonably high, with the judging on the horizontal bar as most consistent and the tumbling least. An examination of the number of times a judge scored high or low was carried out. It was shown that if the scores of all five judges were used in determining the results, definite changes in the individual standings resulted.

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Psychogalvanic and Word Association Studies of Athletes

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Although many phases of competitive athletics have been subjected to careful scientific investigation, very little has been done along lines of systematic exploration of the emotional aspects of such competition—in spite of the fact that most coaches recognize the importance of psychological fitness for optimal performance. The present study is the fourth in a series of "on the spot" studies by the present investigator designed to explore the emotional aspect of athletic sports contests (2).

It must be acknowledged at the outset that emotion is one of the most difficult of all psychophysical phenomena to study—particularly when such study is attempted in *media res* or in the midst of life situations rather than in the laboratory. At the present time neither the precise nature or function of human emotion is known; no one has yet succeeded in defining emotion in an entirely satisfactory way (10). No one has succeeded in measuring emotion in such a way that he could state with confidence: "I am measuring emotion, *per se*." Consequently, it is necessary to deal with the phenomenon indirectly in terms of indices and manifestations; it is also necessary to interpret findings cautiously and tentatively (10).

Purpose of the Study

The concern of this particular study was focused upon the following considerations:

1. An attempt to ascertain something of the emotional intensity of the precompetition experience associated with certain winter sports.
2. An attempt to compare the reactivity of the subjects to different types of critical word stimuli in the word association tests; i.e., to compare the athletes' reactions to both the psychosexual critical and the sports critical words.
3. An attempt to compare the reactions of athletes in various sports to the word stimuli (i.e., to compare wrestlers with swimmers, etc.).
4. An attempt to continue laying the basis for individual and group analysis, along lines of emotional reactions, which shows promise of becoming of value for coaching and other educational purposes (3).
5. An attempt to evaluate the psychogalvanic and word association testing technique as a practical tool for determining the emotional response of athletes.

Subjects of the Research

1. *The experimental group.* This group involved 82 college athletes in four winter season sports; i.e., 24 swimmers, 24 wrestlers, 19 basketball players, and

15 hockey players. These athletes were from such schools as Boston University, Harvard, M. I. T., Tufts, Williams, and Springfield. For purposes of this research an "athlete" was defined as an individual about to participate in an intercollegiate sports contest (i.e., within approximately one hour).

2. *The control group.* This group consisted of 82 college men of a general, athletic appearance but not athletes (as defined), between the ages of 20 and 30 years. This group was selected from a college population. (See Items 1 and 2 in Research Procedure.)

Discussion of the Tools of Research

There were two principal tools of the research, both of which are well established psychological testing devices. A relatively large body of evidence may be cited as justification for using the psychogalvanic and word association techniques in studies of emotional reactivity—in spite of the fact that apparently neither has been used previously in this particular area.

1. *The first tool:* A sensitive psychogalvanometer of a modified Wheatstone Bridge variety was especially designed and constructed for this reasarch. This device conformed to the criteria established by such writers as Ruckmick (8). A considerable amount of preliminary experimentation suggested most practical levels of sensitivity to be used in the investigation. The electrode arrangement was not unlike that frequently seen in certain so-called "lie-detectors"; two 7″ x 5″ aluminum plates were so arranged as to take advantage of the peculiar palmar and finger-pad skin reactivity, which has been investigated and described by such people as Lund and Richter (3, 7). In the interests of gaining the largest possible N and since gross changes were the primary objects of consideration, no effort was made to reduce the relatively minor effects of slight bodily movements or temperature and moisture variations on the electrode plates (7, 8).

Although the precise physiological mechanisms involved in the electrodermal response are not known, the resistance encountered by the current as it passes through the pores of the palmar and plantar regions has been shown to vary with emotional disturbances (3, 7, 8, 10). Used in conjunction with a properly constructed word association test, this electrical device has the advantage of indicating mechanically on the galvanometer a subject's reactions to each word in a series of stimulus words, some of which are important for determining extent and nature of emotional upset.

2. *The second tool:* Two types of word association tests were constructed in accordance with principles established by psychological research.

These word lists of 24 items each were somewhat shorter than those ordinarily employed in word association studies. For his purposes, Rapaporte used a short test composed of 60 words (6) and Luria used as few as 30 (4). Time limitations in the present "on the spot" research dictated the short 24-word test used, particularly since both Type I and Type II word lists (total of 48 words) were administered to all of the athlete group. Furthermore, the *proportion* of critical to indifferent words in the present lists was modeled after that of certain classical studies (4, 6, 9).

Test I: In word association test Type I, 6 "critical" words of a psychosexual nature were interspersed among 18 "indifferent" words. The critical words of this test were carefully selected after an analysis of word association tests of such writers as Jung, Luria, and Rapaporte. Thus, an effort was made to include a verbal representation for a "variety of areas of ideation, conflicts in which are likely to be prominent in the different types of maladjustments" (6, *p. 13 ff.*). All subjects in both experimental and control groups were given word association test Type I.

Test II: In word association Test II, 6 critical words pertaining to significant aspects of each sport were interspersed among the same 18 indifferent words as in Test I.

Whereas in clinical word association testing, words of psychosexual connotation are used to determine areas of psychic conflict (6, 9), in lie detection critical words are selected on the basis of their application to a specific situation, e.g., one involving some criminal act (4). In the latter type, words are chosen which, presumably, will have guilt meaning only to those individuals with an intimate knowledge of the details of the crime. If, for example, a poisonous powder has been the instrument of a murder, and only the actual murderer is aware of this fact, the word "powder" might be expected to be a highly emotionally charged (or cathexed) and thus critical word for the guilty person and an indifferent word for the guiltless suspects who are unaware of the implication of the word "powder." It is likely that the guilty person's reaction to this word would occasion a considerable deflection or other change in the lie detection device being used.

In view of the above discussion regarding selection of critical words on the basis of their meaning in the immediate situation rather than on the basis of association with more basic conflicts, and since the control group (non-athletes) was by definition composed of individuals under no known stress and not particularly emotionally involved in the winter sports under consideration, word association Test II was not administered to the control group. It seemed highly probable that if one of the stimulus word lists would elicit exceptional reactivity from the control group, it would most likely be the list containing the psychosexual critical words. Preliminary testing seemed to confirm the apparent superfluity of administering Test II to the control group. Furthermore, the problems of time limitation and selection of qualified control group subjects in sufficiently large number made administration of Test II to this group impracticable. As has been pointed out earlier, the hypothesis which gave rise to word association list Type II (sports critical words) was comparable to that which explains modern lie detection work; both applications are contingent upon the *disturbed* state of the subject at the time of testing. In both the psychosexual (Type I) and other critical word tests (e.g., Type II) hyper-reactivity has been demonstrated to be dependent upon the existence of a condition of stress on the part of the subjects (4, 6, 9, 10). In this connection, it is of interest to note that in his classical word association studies of criminal and student inquisitions in Russia, Luria described the stress situation imposed on the subjects as provoking a "reaction similar in structure to that of the neurosis; it

creates, as it were, a temporary actual neurosis, which is most distinct in those subjects already having a neuropathic disposition" (4, *p.* 75). Having studied the stress of many combative sport athletes just before they went into action, the present writer reasoned that the pre-contest emotional disturbance might in some instances be of sufficient intensity to approixmate Luria's description of a "temporary actual neurosis." If such were the case, it seemed reasonable that the psychogalvanic-word association technique would be applicable.[1]

In word association test Type II, for each of the four sports, coaches aided in the selection of six representative words which bore directly upon some vital factors in competition. For example, "foul shot" and "the bench" were used in the basketball list, and "take down" and "head lock" in the wrestling list. "Wall," "table," and "grass" are sample indifferent words that were used.

Research Procedure

1. *The experimental group.* Both types of word association tests were administered to the 82 athletes within approximately one hour before their actual intercollegiate competitions. The testing was done in or near the athletes' dressing rooms as the individuals were preparing for the various competitions. The athletes had not eaten within one and one-half hours of being tested, had not exercised earlier in the day, and were not under known emotional stress caused by factors other than their sport.

Prior to testing, the athletes were told the general nature and purpose of the research. The subjects were seated comfortably in some comparatively secluded spot; brief instructions were given to them in which they were asked to rest their hands on the electrode plates, to restrict all bodily movements to a minimum, to keep their eyes closed in order not to be disturbed by other activities in the room, and to respond verbally to each of the investigator's stimulus words with the first word that came into their minds (9). The combination of tests took approximately ten minutes to administer per subject.

Ideally, these same athletes would have been tested again when an athletic contest was not about to take place; thus, direct comparison could have been made on the same subjects between reactions under "normal" and pre-contest situations. However, since the athletes were from a number of universities, it was impossible under the circumstances to make further contact with them.

2. *The control group.* Because the athletic group could not be retested, a relatively large and grossly comparable control group was employed in an effort to ascertain someting of the reactions to the stimulus words of individuals not in an excited state. The psychosexual word association test only was administered to the 82 controls—at times when the subjects were under no known emotional stress, had not exercised earlier in the day, and had not eaten within one and one-half hours. The same procedures were followed here as with the

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[1] For an analysis of disturbances in aviation combat personnel, cf. Grinker & Spiegel, *Men Under Stress.* Philadelphia: Blakiston, 1945.

experimental group. In an effort to make the testing environment comparable to that of the athletic dressing room, the testing of this group was done in a large office in which there was ordinarily a considerable amount of activity.

Treatment of the Data and Findings

The nearly 6,000 individual items were analyzed in such a way as to reveal extent of group reactions to each word. No effort was made in the direction of qualitative analysis of individual responses to the stimulus words. However, beyond a doubt, this aspect of the testing procedure played an important part in the quantitative reactions with which this research dealt (9).

Table 1 shows that in terms of the psychogalvanic response to word stimuli, the athlete group (pre-contest) had a considerably higher mean reaction to the stimulus words in both the psychosexual and sports critical word lists than did the non-athlete control group to the psychosexual list. Furthermore, the statistical treatment indicated that the mean differences (M_{a-1} M_{c-1} ; M_{a-2} M_{c-1}) were true differences at high levels of confidence.

TABLE 1

Mean reactions of the athlete and control groups to the stimulus word lists

Group & test type	N	Mean resistance (R_0–R_1)	Standard deviation	t-test	Confidence level
Athlete, type I	82	$M_{a-1} = 142$	130	$M_{a-1} M_{a-2} = 1.7$	9%
Athlete, type II	82	$M_{a-2} = 131$	72	$M_{a-2} M_{c-1} = 6.2$	under 1%
Control, type I	82	$M_{c-1} = 106$	31	$M_{a-1} M_{c-1} = 7.3$	under 1%

NOTE: Table 1 shows an analysis of the reactions of the athlete group (under pre-contest stress) for both test type I & II (psychosexual and sports critical words) and non-athlete control group for test type I (psychosexual critical words). 5,904 total test items.

TABLE 2

Comparison of the four sports in terms of reactivity to both the sports and psychosexual word lists

Sport	N	Mean (ohms) R_0-R_1
Basketball	19	210
Swimming	24	130
Wrestling	24	120
Hockey	15	120

NOTE: Table 2 shows the mean reactivity of the athletes tested to the psychosexual stimulus word list. The basketball group was reactive at a significantly higher level than the others.

A graph was constructed showing the mean reactions of the groups from word to word of the word association lists. As may be seen in Figure I, the pre-contest or "stress" situation gave rise to much greater psychogalvanic deflections in both the psychosexual and sports critical words (words 4, 8, 11, 15, 20, and 23) than did the "undisturbed" condition in which the controls were tested. The indifferent words resulted in somewhat smaller deflections in the athlete group test Type I, than in the others.

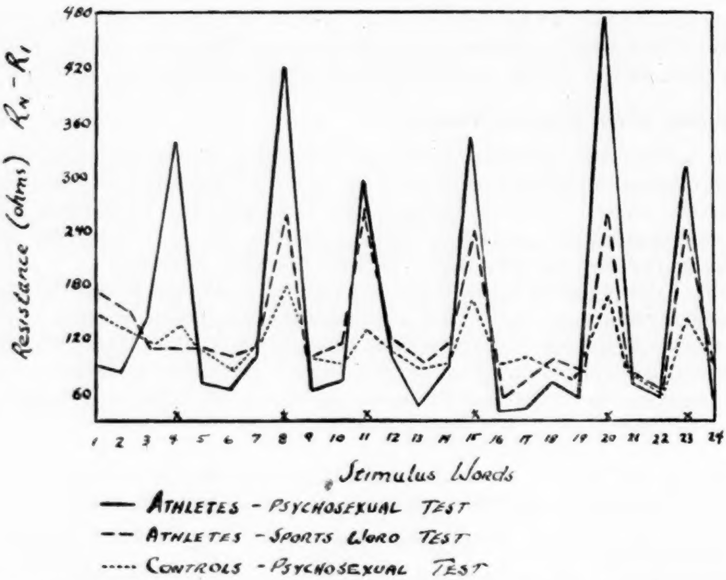

FIG. I shows the relative mean psychogalvanic deflections of the two athlete group tests and the control group test. Words 4, 8, 11, 15, 20, and 23 are the critical words in both the psychosexual and sports critical word lists.

In both graphic and statistical treatments, the 19 basketball players stood out as being decidedly more reactive than the other athletes; i.e., at less than the 1 per cent level of confidence. Tests of significance indicated that, except for basketball, none of the observed mean differences among wrestling, swimming, and hockey, were true differences at high levels of confidence.

Conclusions and Discussion

1. In terms of the techniques of the present study, the pre-contest situation of the sports tested is evidently characterized by a tendency towards exaggerated psychogalvanic reactivity.[2] The athletes as a group were found to be very significantly more reactive to both types of critical word stimuli employed than were the controls who were under no known emotional stress. However, attention is called to the consideration that the "disturbed state" that so commonly characterizes the pre-contest situation is probably not detrimental to individuals who are comparatively free of profound personality disturbances. Indeed, within limits, varieties of emotional disturbance probably serve to improve neurological and endocrine integration for competitive action (1).

[2] And thus, the pre-contest situation may, perhaps, be said to approximate Luria's definition of a "temporary actual neurosis" (4, p. 75).

2. The athlete group reacted vigorously to both the psychosexual and sports critical words.

3. In no case did men who are considered outstanding performers by their coaches react in an extreme manner.

4. Only the basketball players stood out as being significantly higher in reactivity than the other athletes. This fact is not consistent with the writer's previous findings in which the individual and combative athletes were characterized by greater emotional disturbance as indicated by other types of physiological tests. The deviation of the basketball players may conceivably have been due to coaching techniques or to the personality structure of these particular subjects. In all events, taken individually, these athlete groups are obviously too small to justify conclusive interpretation.

5. Evaluation of the technique. The psychogalvanic-word association technique is of experimental interest because it suggests something of the nature and extent of the psychophysical disturbance occasioned by athletic sports competition. Consequently, it may be said that such information contributes to a more precise understanding of that phase of physical education which has to do with intercollegiate competition.

It is unlikely, however, that the present technique will prove of practical value as a coaching tool. Use of the apparatus and word lists requires a certain degree of technical investigation and practice, and in addition, the actual administration of the tests is time-consuming and exacting. Although the athletes themselves have almost invariably been extremely co-operative and very much interested in the research, the time of testing before competition is usually difficult for investigator and subject alike.

A great deal more research must be conducted with these techniques before psychogalvanic reactions to the stimulus words can be accurately interpreted in terms of their implications for championship personality structure and individual "readiness" for competition.

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Opportunities in General Science for Health Instruction

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HEALTH education aims at the conservation of our most important resource —our boys and girls. American schools at secondary level present to the pupils instruction in health with the wholesome aim that those receiving the instruction may be stronger, healthier, and happier. Besides forming the basis of the secondary school course in health, health subject matter is present in other courses; this is true in the case of general science, the generally required course presented at the secondary level for the purpose of developing attitudes and concepts in general science. It is the purpose of this article to show some of the health topics that are found in current general science material and to present these topics as opportunities for teaching and planned integration between health instruction and general science.

For the purpose of this article the following shall be assumed as definitions of health education, health instruction, and concepts. Health education[1] is the sum of experiences which favorably influence practice, attitudes, and knowledge relating to health. Health instruction[2] may be any instruction that is carried on as direct health instruction or that is integrated into the curriculum. Concepts[3] are the teacher's goals. They are recognizable advances to be made by the pupil.

Procedure

In order to estimate the health material in general science, a list of health concepts[4] was taken from 14 approved health sources—seven textbooks in health and seven courses of study in health. From these sources there were listed 931 concepts under the following 26 health topics:[5] (1) Food; (2) Cleanliness; (3) Disease; (4) Posture, Care of the Feet, and Exercise; (5) Air and Sunlight; (6) Teeth; (7) Clothing; (8) Sleep and Rest; (9) Eyes; (10) Alcohol, Tobacco, and Drugs; (11) First Aid; (12) Mental Hygiene; (13) Arousing a Desire for Health; (14) Safety; (15) Height and Weight; (16) The Heart and Blood; (17) Elimination of Body Waste; (18) Health Agencies; (19) Nose and

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[1] National Education Association and American Medical Association. *Health Education*, 1948. p. 4.

[2] Ruth Grout. *Health Teaching in Schools*. p. 9.

[3] Roy O. Billett. *Fundamentals of Secondary School Teaching*. p. 273.

[4] Ruth Strang. *Subject Matter in Health Education*. p. 10.

[5] Frederick A. Meier. *The Study of Opportunities in General Science as a Contribution to Health Instruction*. 1950. 250 pp.

Throat; (20) Hair; (21) Ears; (22) Education for Parenthood; (23) Defects in General; (24) Home and Family; (25) Industrial Hygiene; and (26) General Physiology.

Under each topic the concepts, written in complete sentences, from health sources were arranged consecutively. These concepts were checked to eliminate repetition. The 14 general science sources—seven textbooks and seven courses of study—were then checked for the appearance of these concepts, and they were likewise arranged under the 26 topics. To aid in the compiling of the data, a code was constructed identifying the concepts. Using the numbering of the topics, 1–26, as they occur in the preceding list, the code shows the topic number in the first one or two digits and the number of the concept under the topic in the next one or two digits. Thus, it was possible to tabulate the appearance in the source material of the individual concept in both health and general science.

A sample table is shown herewith:

SAMPLE TABLE

Table III.—*Distribution of Concepts on Disease*

Concept	Health Texts	Sources C.S.	Total	General Texts	Science Sources C.S.	Total
301	4	4	8	2	1	3
302	3	1	4	4	2	6
303	4	0	4	0	1	1
304	2	1	3	0	1	1
305	3	1	4	0	0	0
306	1	1	2	1	2	3
307	1	2	3	0	2	2

The placement of all 931 concepts in the health material and 377 in the general science material was recorded in 26 tables.

The brief sample of Table III may serve to show what the tables tell about the placement of the concepts as they occur in the health or science sources under each topic. *Disease* is the third topic in the list of 26 topics and 75 concepts appear under this topic from health sources. Of the 75 concepts, 57 appear in at least one science source. Applying the code and using the sample of Table III, the reader may see that concept 301 was found in four health texts and four health courses of study for a total of eight health sources whereas it was found in two general science texts and one general science course of study for a total of three general science sources. By referring to the list of concepts in the original study, he may find that concept 301 (i.e. the first concept under the third topic) reads "Knowledge of how germs and infections are spread is important in maintaining good health." The second concept under the third topic is 302 and reads "Germs are living things of microscopic size."

Reference to Table III shows that for health this idea of #302 was found in three textbooks and one course of study, while for general science it appears in four textbooks and two courses of study. Such determinations were made for the entire 931 concepts under the 26 topics.

Results

In order to reach some areas in the teaching of health, topics can be taught for health within the prescribed hours of general science. For example, in a required general science course of three or four class hours per week, one hour might be devoted to the teaching of the concepts under topics that are rich in health material. The following topics, arranged in descending order according to the number of concepts listed from health sources, are those in which the data show there is opportunity for co-operative teaching between the courses in health and in general science.

Disease—75 concepts are listed from the health sources, and of these, 57 are found in the general science sources.

Eyes—58 concepts are listed from the health sources, and of these 22 are found in the general science sources.

Food—55 concepts are listed from the health sources, and of these 34 are found in the general science sources.

Heart and Blood—46 concepts are listed from the health sources, and of these 20 are found in the general science sources.

Air and Sunlight—35 concepts are listed from the health sources, and of these 17 are found in the general science sources.

Education for Parenthood—34 concepts are listed from the health sources and of these 12 are found in the general science sources.

General Physiology—31 concepts are listed from the health sources, and of these 24 are found in the general science sources.

Elimination of Body Waste—29 concepts are listed from the health sources, and of these 10 are found in the general science sources.

Ears—25 concepts are listed from the health sources, and of these 15 are found in the general science sources.

Nose and Throat—19 concepts are listed from the health sources, and of these 6 are found in the general science sources.

The pupil should have the opportunity to receive instruction in all important phases of healthful living. Since the following topics are not treated adequately in general science it is important that they be dealt with in formal health instruction.

Alcohol, Tobacco, and Drugs—63 concepts are listed from the health sources, and of these 29 are found in the general science sources.

Teeth—57 concepts are listed from the health sources, and of these 6 are found in the general science sources.

Posture, Care of the Feet, and Exercise—51 concepts are listed from the health sources, and of these 11 are found in the general science sources.

First Aid—51 concepts are listed from the health sources, and of these 30 are found in the general science sources.

Mental Hygiene—41 concepts are listed from the health sources, and of these 5 are found in the general science sources.

Sleep and Rest—39 concepts are listed from the health sources, and of these 8 are found in the general science sources.

Saftey—38 concepts are listed from the health sources, and of these 8 are found in the general science sources.

Health Agencies—34 concepts are listed from the health sources, and of these 18 are found in the general science sources.

Cleanliness—27 concepts are listed from the health sources, and of these 8 are found in the general science sources.

Home and Family—26 concepts are listed from the health sources, and of these 9 are found in the general science sources.

Clothing—26 concepts are listed from the health sources, and of these 13 are found in the general science sources.

Arousing A Desire for Health—19 concepts are listed from the health sources, and of these 8 are found in the general science sources.

Hair—19 concepts are listed from the health sources, and of these 7 are found in the general science sources.

Industrial Hygiene—16 concepts are listed from the health sources, and of these not one is found in the general science sources.

Height and Weight—14 concepts are listed from the health sources, and of these 3 are found in the general science sources.

Defects in General—3 concepts are listed from the health sources, and of these not one is found in the general science sources.

Conclusions

Of the 931 concepts determined from the health sources, 377 of these identical concepts were found in the general science sources examined. In view of the above findings, it seems apparent that:

1. Health educators, general science teachers, and makers of courses of study should direct their attention toward the health content in general science.

2. General science teachers should become acquainted with the topics in general and the concepts in particular that deal with health in their field.

3. Health educators should use the concepts found in general science as aids in planning more specific, co-operative teaching between health instruction and general science.

4. School administrators should use the health concepts found in general science to insure a minimum of teaching for health where formal health courses have not yet become an integral part of the secondary school curriculum.

5. It is not the intention of the author to imply that because a concept exists in one field it should be excluded from the other field. A certain amount of overlapping is desirable for learning. The aim of cooperative teaching for health is to avoid useless repetion between the two fields and to provide articulation of the important concepts in both fields.

6. It should be borne in mind that similarly—worded concepts in the two fields are not necessarily equivalent in instructional value because of differences in instruction and in method.

It is not recommended that any broad fields of health instruction—such as foods, disease, etc.—should be omitted entirely from formal health instruction;

however, certain concepts from these topics may be vitally and efficiently taught in other subject-matter fields if consideration is given not only to the health content involved but also to the health attitudes and objectives necessary for the complete development of the concept. Through planned integration and cooperative teaching, the subject-matter field of general science offers many specific opportunities in health instruction.

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A Mathematical Description of the Heart Rate Curve of Response to Exercise

With Some Observations on the Effects of Smoking

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This study is concerned with the consideration of two problems. They are both being reported in the same article because they use the same data and are related in other ways. The first problem can be introduced very briefly: The writer has been impressed by the similarity of graphs of the pulse rate response to exercise and oxygen consumption graphs. It seemed worth while to find out if both could be described by the same type of mathematical equations.

The second problem has to do with the effect of tobacco smoking on the response of the heart to moderate exercise, insofar as it is measured by the pulse rate. It seemed to be well-established that smoking increases the resting pulse. A recent paper by Henry and Fitzhenry (5) gives a number of references to the literature on this topic. Other references of interest include the study of Sollman (9), who reported a pulse rise of 20 percent in non-habitual smokers plus a rise in blood pressure. Habitual smokers seemed to have no blood pressure rise and little or no change in heart rate, although they as well as the non-smokers responded with prompt and persistent cutaneous vasoconstriction after smoking one cigarette. Karpovich (7) states that the increased pulse rate caused by smoking may be considered to be an indication of decreased oxygen-carrying capacity of the blood, which of course would handicap a person during severe exertion.

One of the first studies of the effect of smoking on the recovery of the heart rate after exercise is the report by Fisher and Berry (1). Seven smokers and eight non-smokers exercised 5 to 10 times after smoking two cigars in an hour. The recovery times for smokers was an average of 0.2 minutes longer than for non-smokers in the control tests and 0.9 minutes longer after the smoking tests. In 74 out of 118 experiments, pulse rate increased and had not returned to normal within 15 minutes after smoking. This occurred for 72 percent of the non-smokers and 56 percent of the smokers. The exercise was mild, 20 "jumps" in 15 seconds. Juurup and Muido, (6), using a much harder exercise, tested 4 subjects and found that smoking one or two cigarettes elevated the resting pulse rate and the amount of increase in response to exercise. Reeves and Morehouse (8) gave 15 habitual smokers a cardiovascular fitness test under controlled conditions and after cigarette smoking. No effect of smoking was observed, either in this test or in test of speed, strength, power and endurance.

Henderson, Haggard and Dolley (2) have discussed the probable detrimental effect of the high pulse rate due to smoking. With a rapid pulse, stroke volume would be decreased, and this would probably carry over to the heart rate response to exercise. Since the heart is inefficient when beating very rapidly, smokers would have less cardiac reserve to draw on during vigorous exercise.

Method and Procedure

The subjects tested for this study were 20 university men between the ages of 22 and 27, ten of whom were smokers. The criterion for a smoker was established as a man who smoked every day (any number of cigarettes) and who inhaled.

All subjects were tested at the same time every day—mostly between 10:00 a.m. and 12:30 p.m. They had refrained from smoking or eating for at least two hours before the test.

Each subject was tested three times smoking and three times non-smoking. Tests were given alternately, and half of each group started on the smoking test and the other half started on the non-smoking test in order to minimize practice effects. For the non-smoking test, the subject was seated for at least five minutes and then heart rate was recorded until a definite steady resting level was established. The subject then performed an exercise consisting of stepping up and down on a one-foot high platform to the cadence of a metronome. Each subject did 36 step-ups per minute for two minutes. At the end of the exercise the subject was seated and heart rate was recorded until it definitely leveled off for a period of several minutes.

Procedure for the smoking test was identical with the exception that the subject smoked (inhaled) one cigarette in approximately three minutes immediately after the resting heart rate had been established. Heart rate was recorded during this time and for two minutes after smoking ended, whereupon the exercise proceeded and the recovery took place.

Recording of the heart rate, number of step-ups, and time (in seconds) was done by the Henry Electrocardiotachometer.[1] Electrodes were strapped across the chest of the subject over the apex and base of the heart (using Redux electrode paste to reduce skin resistance), thus picking up the action potential of the heart which was amplified, run through an electrical counter, and relayed to where it was recorded on moving paper. Simultaneous recordings were made of seconds via a telechron electric motor, and step-ups were recorded through a signal magnet connected to the top of the step-up platform. A more detailed description of the cardiometer is given elsewhere (3).

Since none of the subjects were familiar with the equipment, and since the non-smokers also had to learn to inhale, it was decided in advance that there might be considerable psychological effects from the first tests. Therefore, the first test of each kind was treated as a practice run and all determinations were made from the second and third trials of both tests.

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[1] The writer wishes to express appreciation to Dr. Pauline Hodgson for the loan of this equipment and laboratory space, and for other help during the course of the investigation.

Results and Discussion

In Figure 1, it can be seen that the amount of increase in pulse rate due to the exercise and the curve of recovery to the resting level are described very accurately by the logarithmic formulae, which are very similar to the mathematical expressions that have been used for oxygen intake during exercise, and for oxygen debt pay-off (4). The main difference is that the pulse curve is a two component system, the first component $A_1(1 - e^{-k_1t})$ describing the increase in the pulse rate during the first 10 or 15 seconds of exercise. This phase can be considered as a logarithmic approach to the limit A_1, which is about 20 beats per minute. It is a very rapid phase, having half its effect in less than two seconds of exercise and being 90 percent completed within 7 seconds. The second component $A_2(1 - e^{-k_2t})$ accounts for the main part of the increase during exercise, and determines the slope of the pulse rate curve after the first 10 or 12 seconds. It has a much slower velocity constant, half the effect occurring 30 seconds and 90 percent in about $1\frac{1}{2}$ minutes. The rate is still going up at the end of two minutes, and the indications are that it would require about 4 minutes for a steady state to be reached. The velocity constant "k" of this component is the same in magnitude as the aerobic oxygen consumption "k," which also has a half-time characteristic of about 30 seconds (4).

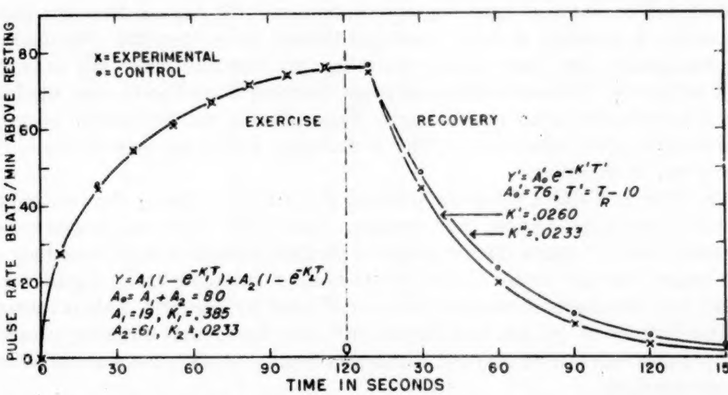

Fig. 1. Pulse rate during Exercise and Recovery. The smooth curves were calculated from the formula and the marked points represent actual counts. Twenty subjects were tested under control condition and after smoking (experimental conditions).

The recovery rate "hangs on" at the exercise level for 10 seconds or more after the subject has stopped moving before it begins to recover. The first 30 seconds of recovery have not been studied very carefully, so it has not been determined if the fast component logarithmic drop shows up here.[2] The formula

[2] The writer is indebted to Dr. Franklin Henry for setting up the mathematical equations used in this study. It is Dr. Henry's opinion that if the first 25 or 30 seconds of recovery

given in Figure 1 describes the recovery pulse with a velocity constant *k* that is on the average a little faster than the main *k* observed during exercise, but the difference is very small.

The data (Table 1) show the commonly accepted effect of smoking raising the resting heart rate. The average increase for all subjects, when sitting, was 7.7 heart beats. Heart rate increase due to smoking for smokers was only 0.4 more than the same effect on non-smokers. If anything, this greater effect on smokers is less than would be expected, since they probably inhaled more smoke than the "new smokers." Increases in heart rate for all subjects ranged between +2 and +26 (recorded 2 minutes after smoking) and in no instances were heart rates the same or lower than the resting rate before smoking. The ratio of the mean differences to the standard error of the differences (t ratio) is 6.03, which is significant at better than the one percent level of confidence.

All subjects started the exercise at an average heart rate of 10.8 beats faster on smoking days than on non-smoking days. The mean heart rate, standing just before exercise, was 66.2 for the non-smokers on the days they exercised without smoking, and 71.6 on the days they exercised after smoking. The "t" ratio, 2.09, is not high enough to be statistically significant. The habitual smokers had a heart rate of 72.7 on control days and 77.9 on experimental (smoking) days. However the "t" ratio, 1.92, is not significant.

Both before and after smoking, and on non-smoking days, sitting and standing smokers averaged 6 heart beats per minute more than the non-smokers. Physiologically, the faster heart rate is less efficient and hence not desirable. Add to this the 10.8 hearts beats (average) increase immediately after smoking, and a less efficient heart rate is found. This still may not be harmful or create a noticeable effect unless an activity is maximal, but in any case it would certainly not be desirable.

The data in Table 1 show the increase in heart rate during the two minute exercise (smoking against non-smoking tests) for both non-smokers and smokers. The "t" ratios for the points of greatest difference show that they are not larger than can be accounted for by random sampling error. Figure 1 also shows that the response to exercise is not affected by smoking. This is contrary to the findings of Juurup and Muido (6), who found that smoking caused a higher pulse rate during exercise, although oxygen consumption was not altered by the smoking.

Contrary to the writer's expectation, the speed of recovery is not slowed down by smoking. If there is any difference, it is in the direction of faster recovery after smoking, as shown in Figure 1. The semi-log plots in Figure 2 show that the habitual smokers show the effect to a greater degree, as their recovery "k" is 0.0299 after smoking compared with 0.0247 when they exercised under the control conditions.

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pulse is counted in very short time-intervals, it will turn out that the exercise pulse "hangs on" for at least 15 seconds and then drops very rapidly according to the "fast" component that was found at the beginning of exercise. Then the formula for the post-exercise pulse will be of the form $Y = A_1e^{-k_1t} + A_2e^{-k_2t}$

TABLE 1

Mean Pulse Rates of ten non-smokers and ten habitual smokers, Tested under Experimental Conditions (After Smoking a Cigarette) and Control Conditions (Without Smoking)

	Exercise									Recovery						
Mid-point of pulse count (sec.)	0	7½	27½	37½	52½	67½	82½	97½	112½	10	30	60	90	120	150	180
Non-smokers																
Experimental	72	102	121	131	137	144	148	150	151	150	119	95	83	78	77	78
Control	66	102	119	129	136	143	146	149	152	152	121	97	84	79	76	77
Smokers																
Experimental	78	104	120	129	136	142	146	148	150	150	123	99	89	85	85	84
Control	73	105	120	129	137	142	145	149	150	150	122	98	87	82	79	77
Average for non-smokers (all tests)	69	102	120	130	137	144	147	150	152	151	120	96	84	79	77	78
Average for smokers (all tests)	75	105	120	129	137	142	146	149	150	150	123	99	88	84	82	81
Average experimental (all subjects)	75	103	120	130	137	143	147	149	151	150	121	97	86	82	81	81
Average control (all subjects)	70	104	120	129	137	143	146	149	151	151	122	98	86	81	78	77

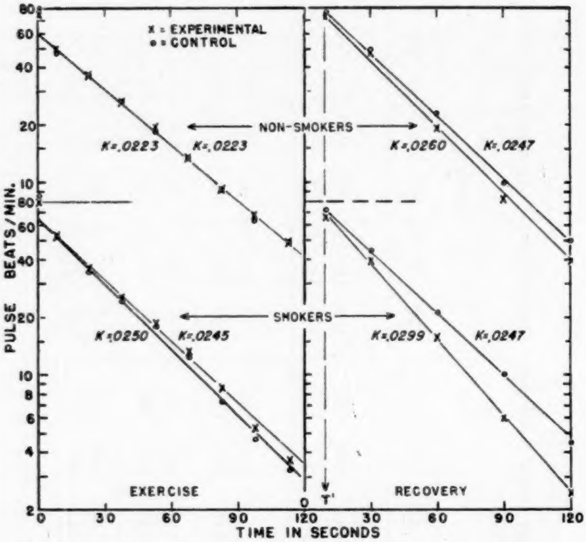

Fig. 2. Semi-log Plots of Pulse Rate Adjustment. The exercise graphs represent the difference between the observed pulse rate and the steady-state rate. The recovery graphs represent the difference between the observed rate and the post-exercise resting level.

The habitual smokers, when compared with the non-smokers, show a faster adjustment to the exercise, their "k's" for the main component averaging 0.0248 against 0.0223 for the non-smokers. Their rate of recovery is also faster, as the recovery "k's" of the smokers are 0.0247 and 0.0299 compared with 0.0247 and 0.0260 for the non-smokers. These differences in rate of recovery are *not* caused by the fact that the slowing of the pulse necessary to accomplish recovery is less because their resting rate is higher. Their *rate* of approaching the base line could either be faster or slower. The facts are that it is faster.

When the pulse counts during recovery are compared, the counts are significantly greater after smoking at the time $2\frac{1}{2}$ minutes after recovery ("t" = 2.00, all subjects) and at 3 minutes also ("t" = 2.31, all subjects), but not at 4 minutes ("t" = 1.76, all subjects). The difference is much less than that reported by Fisher and Berry (1), probably because their subjects smoked two cigars in one hour compared with one cigarette in 3 or 4 minutes in the present experiment. The exercise of the present experiment was much harder than theirs, but it still was not hard enough to get the heart rate up to 180 or 200 beats per minute where larger losses in efficiency might be expected from high heart rates. The results too clearly show that smoking a cigarette or being a habitual smoker does not cause inefficiency during moderate exercise, even though the resting pulse rate is higher due to smoking.

Summary and Conclusions

Ten smoking and ten non-smoking subjects were tested for the effects of smoking on heart rate during and following an exercise consisting of 36 one-foot

step-ups per minute for two minutes. Each subject performed the exercise three times without having smoked previously, and three times just after smoking one cigarette. A continuous record of the heart rate during and after exercise was made for all subjects.

The heart rate was found to increase during exercise as a logarithmic function of time, according to a two-component mathematical system. The first fourth of the increase occurred very rapidly with a half-time velocity constant of less than two seconds. The remainder of the increase occurred more slowly with a half-time of 30 seconds. Recovery was also found to proceed as a logarithmic function of time, with the main component having a half-time of 30 seconds, which speeded up to 27 seconds when the exercise had been preceded by smoking.

It was found that the resting heart rate (sitting) was significantly higher at better than the one percent level of confidence after smoking one cigarette. The standing pulse rate was significantly higher above the 5 percent level of confidence after smoking. At no time was the heart rate during exercise after smoking significantly different from that when no smoking preceded the exercise. No significant difference was found between non-smoking and smoking recovery until two and one-half minutes after exercise, whereupon smoking recovery leveled off at a position significantly higher than the level of non-smoking recovery after exercise. Smoking previous to exercise did not lower the average rate of recovery for the 20 subjects in this experiment. Habitual smokers tended to show a faster adjustment to exercise and a faster rate of recovery than non-smokers.

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Research Abstracts

Continued from the October Quarterly

Prepared by the Research Abstracts Committee of the National Council of the Research Section, Carolyn W. Bookwalter, Chairman

Education and Psychology

53. Clark, James F. Junior college public relations: a survey. *School and Society*, **74,** 1913: 104–107 (Aug. 1951).

Questionnaires were sent to 444 member colleges of the American Association of Junior Colleges asking about their public relations programs. Responses were obtained from 236. From the survey two out of three junior colleges do not have a concerted effort in public relations. Of those engaging in public relations the activities rank as follows: 1. publicity, 2. new student promotion, 3. publications, 4. staff responsibilities, 5. advertising, 6. alumni relations, 7. special events planning, 8. community integration, 9. professional relations, 10. radio-T.V. programming, and 11. fund raising.—*Carolyn Bookwalter.*

54. Hoff, Charles. Trends in fees, salaries, and enrollments in 497 colleges and universities. *School and Society*, **74,** 1915: 135–139 (Sept. 1, 1951).

This study was made by the Central Association of College and University Business Officers from 1945–1951. The last survey revealed information upon which to base an estimate that there would be 17.7% fewer students enrolled in colleges in September 1951 than in September 1950. Tuition fees have been raised by an average of 61% in 407 institutions since 1941. The average monthly rate for room rent was $16.54 (two persons in a room). Faculty and administrative salaries have increased only 60% since 1940. Joint-contribution retirement plans are operated in 91% of the colleges and universities reporting.—*Carolyn Bookwalter.*

55. Prout, Curtis T., M.D. Psychiatric aspects of asthma. *The Psychiatric Quarterly*, **25,** 2, 237–250 (Apr. 1951).

An historical review of the literature revealed evidence of psychic factors affecting asthma. In five cases reported in the study, three were non-psychotic and classed as psychoneurotic and two had illnesses of psychotic proportions. Evidence is shown that psychic factors play an important role.—*Carolyn Bookwalter.*

56. Jarrett, R. F. and F. M. Henry. The influence on error of replicating measurements for individuals. *J. Psychology*, **35:** 175–180 (1951).

The most efficient way to do an experiment that requires the testing of individuals can be determined by considering the relative influence on total error of increasing the number of individuals (n) compared with increasing the number of measurements per individual (k). In general, the mean score will be more dependable as either n or k is increased, but the error of the mean is reduced much more effectively by increasing the number of individuals (n) than by duplicating measurements (k). While the degree of advantage from increasing n rather than k depends on the reliability coefficient, being greatest for high reliability, it turns out that n has a four-fold advantage over k even with the very low reliability of $r = 0.1$. The variance of a mean based on replicated measurements must be calculated by determining the mean score for k measurements for each individual and dividing the variance of this *population of means* by n; otherwise the standard error of the mean will be underestimated.—*Franklin Henry.*

Anatomy and Physiology

57. Berwick, Mary C. The effect of anesthetics on calcium release. *J. Cell. and Comp. Physiol.*, **38:** 1 (Aug. 1951).

The muscle fibers were removed from the combined right and left gastrocnemei of 4 frogs, thoroughly mixed, and divided into 4 equal parts. One of the 4 parts was placed in 2% ether-

Ringer solution, and second in 0.4% chloroform-Ringer solution, a third in 2% cocaine-Ringer solution, and the fourth in frog Ringer solution (control). After one hour of soaking, the fibers were removed by filtration. Aliquots of each soaking solution were removed for determination of calcium. The filtered muscle fibers were then subjected to ultrafiltration. The calcium in aliquots of the ultrafiltrate was determined as a measure of the free calcium in the fibers. The fibers themselves were ashed and their calcium content determined as a measure of bound calcium in the fibers. The calcium was determined by the method of Larson and Greenberg.

The amount of calcium present in untreated fibers of frog gastrocnemius muscle was found to be extremely variable. More calcium was found to be released from muscle fibers treated with experimental anethetic solutions than from muscle fibers treated with control Ringer solutions. Of the anesthetics used, more calcium was released by the fat solvent anesthetics, ether and chloroform, than by cocaine. Most of the calcium released was found in the experimental and control soaking solutions. The results indicate that the production of anesthesia in muscle cells is associated with the release of an unusual amount of free calcium.—*The Wistar Institute.*

58. Lavarack, John Ochiltree, Sidney Sunderland, and Leslie John Ray. The branching of nerve fibers in human cutaneous nerves. *J. Comp. Neur.*, **94**: 2 (Apr. 1951).

Human cutaneous nerves have been examined for branching of fibers in the main trunks. The method employed was to prepare transverse sections, stained by an osmic acid technique, from each nerve at two widely spaced levels. The total fiber count and fiber caliber spectrum at the one level were then compared with the corresponding values at the other. The nerves selected for investigation were the superficial radial nerve at the elbow and in the forearm where it emerged from beneath the tendon of the brachioradialis muscle, and the sural nerve in the popliteal fossa and in the calf before its union with the sural communicating nerve. The nerves were obtained from two autopsy subjects and three specimens of each were examined. In all except one nerve there was a significantly greater number of fibers and a change in the fiber caliber spectrum at the distal level. From this it was deduced that some fibers branched between the levels examined. The magnitude of the increase in number of fibers indicated that less than half of them had branched between these levels.—*The Wistar Institute.*

59. Noback, Charles Robert and George Gordon Robertson. Sequences of appearance of ossification centers in the human skeleton during the first five prenatal months. *Am. J. Anat.*, **89**: 1 (July 1951).

The time of onset of ossification of bones appearing during the first five prenatal months in man is based on an examination of 136 embryos which had been cleared and stained alizarin red. An analysis of the data reveals that within specific regions groups of ossification centers appear in definite sequences. In the skull, the sequence of centers is (1) facial costal, (2) thoracic vertebral, and (3) sternal. In the vertebral column, the centers of the centra and neural arches appear concurrently. The neural arch centers appear cephalocaudally while the centra centers, which appear first in the lower thoracic region subsequently appear cephalically and caudally from their initial site of appearance. In the upper extremity, the sequence is (1) humerus, (2) radius, (3) ulna, (4) distal phalanges, (5) metacarpals, (6) proximal phalanges, and (7) middle phalanges. In the lower extremity, the sequence is (1) femur, (2) tibia, (3) fibula, (4) metatarsals, (5) distal phalanges, (6) proximal phalanges, and (7) middle phalanges. The pectoral girdle centers appear before the pelvic girdle centers. The sequence is (1) clavicle, (2) scapula, (3) ilium, (4) ischium, and (5) pubis. The observed variation in the time of appearance of each primary ossification center and asymmetry in the time of appearance of the bilateral centers are noted.—*The Wistar Institute.*

60. Trotter, Mildred and Goldine C. Gleser. The effect of aging on stature. *Am. J. Phys. Anthrop.*, **9**: 3 (Sept. 1951).

Data from 855 American Negro and White cadavers accumulated over a period of 22 years have been studied to determine changes having taken place in stature after maturity. Since the average stature of cross-sectional groups of individuals may be affected by both age

and secular changes the high relationship of long bone length to stature was utilized in order to separate the age and secular factors. The change in stature with age which is not associated with variance in bone length was obtained by means of partial correlations for groups of Negroes and Whites of each sex. It was found that: (1) there is a statistically significant decline of stature with age in each sample; (2) this relationship is homogeneous for Negroes and Whites for both sexes so that an estimate of the partial correlation for the total population studied was −0.25; (3) the rate of decrement is likewise uniform in all groups and amounts to an estimate of 1.2 cm per 20 years; (4) the assumption of linearity of regression of stature with increasing age is not untenable. Rollet's data based on 50 male and 50 female French cadavers were found to show the same relationship of stature to age as exists in the American samples, yielding again an estimate of 1.2 cm decline per 20 years. Thus, it is indicated that this average rate of decline in stature may be applicable to the general population.—*The Wistar Institute.*

Nutrition

61. Armbruster, Gertrude Dorothy Amanda and Hazel Clara Murray. The effect of canning procedures on the nutritive value of the protein in peas. *J. Nutrition*, **44**: 2 (June 1951).

Three samples of Alaska peas were studied to determine the effect of the heat treatment used in canning procedures on the biological value of the protein. Preparation of the peas involved soaking overnight, parboiling in the same water for five minutes, canning, autoclaving at ten pounds pressure for 40 minutes, drying the contents of the can, and grinding to a flour. The biological value of the protein of the peas was determined by the rat growth method.

Canning procedures did not alter the biological value significantly, but in the case of samples I and III rats on the canned peas showed 13% and 9% lowered growth levels, respectively. Supplementing raw peas with methionine raised the biological value 109%. When lysine was used to supplement raw peas, there was a 20% increase in the biological value; when it was used to supplement canned peas, a 15% decrease resulted. Determination of the apparent digestibility for the rat of raw vs. canned peas showed that the canned peas were 5% less digestible. Chemical and microbiological studies showed that canning decreased the content of reducing sugar by a range of from 30 to 50%; amino nitrogen, 3 to 38%; and methionine, 12 to 28% of the values obtained for raw peas.—*The Wistar Institute.*

62. Asimov, Isaac, Henry Martyn Lemon, Rose Medina Reguera, Marjorie Moira Davison, and Burham Sarle Walker. Ratio of desoxypentosenucleic acid to potassium in normal and malignant human tissue. *J. Cell. and Comp. Physiol.*, **37**: 3 (June 1951).

The desoxypentosenucleic acid concentrations in a variety of human tissues, including both cancerous tissue and normal tissue of homologous origin, are determined. Of the tests for desoxypentose derivatives in the literature, those involving sulfite-decolorized fuchsin cysteine (Stumpf) and phloroglucinol (von Euler and Hahn) form unstable colors. The tryptophane method (Cohen), while otherwise acceptable, is less sensitive than the diphenylamine method (Dische) and is interfered with by proteins to a greater extent than is the diphenylamine method. This last named method is one of choice, therefore, for application to the direct determination of DNA in the intact tissue sections. Potassium content of equivalent sections (obtained by serial sectioning technique) was used as a measure of the total metabolizing tissue present, and was determined by flame photometer. The DNA concentrations per unit potassium were found to be relatively constant in the tissues tested and to show no marked difference in the cancerous as opposed to the normal tissues. It is suggested that differences in the DNA of the cancerous and normal tissues, if they exist, may be not those of quantity merely, but, more probably, involve changes in nuclei acid structure.—*The Wistar Institute.*

63. Bricker, Mildred Lavern and Janice Minerva Smith. A study of the endogenous nitrogen output of college women, with particular reference to the use of the creatinine output in the calculation of the biological value of the protein of egg and of sunflower seed. *J. Nutrition*, **44**: 4 (Aug. 1951).

A study of the endogenous nitrogen excretion of 25 female subjects, 19 to 30 years of age, is reported. The main daily endogenous urinary nitrogen excretion was 1454 ± 30.8 mg. for 14 days of low-nitrogen feeding. When this value was expressed in milligrams per kilogram of body weight, milligrams per square meter of surface area and milligrams per basal calorie, the resulting values were 25.2 ± 0.65, 898.0 ± 17.0 and 1.14 ± 0.021, respectively. The creatinine nitrogen constituted one-fourth of the total endogenous urinary nitrogen (actual mean value, 25.1% ± 0.40). The average metabolic fecal nitrogen excretion was 0.88 ± 0.028 mg per gram dry matter consumed. Biological value and true digestibility of sunflower seed flour (Thomas method) average 60.4 ± 2.28 and 89.6 ± 1.12 for 14 of the above subjects. Estimation of these values by use of the $\frac{CN}{EN}$ ratio and the factor for dry matter consumed resulted in values of 61.6 ± 3.20 and 89.9 ± 1.26. Similar comparisons for whole egg protein, using 10 of these subjects, resulted in determined values of 92.0 ± 2.35 and 94.9 ± 1.36. Although close agreement was found in estimated and determined biological values and digestibilities for the two foods reported, the authors point out that greater differences might be found if these factors were applied to larger and more varied segments of the population.—*The Wistar Institute.*

64. Hoagland, Ralph, Ned Royce Ellis, Orville Gerber Hankins, George Gould Snider, and Richard Lee Hiner. Supplemental value of certain amino acids for lamb protein and nutritive value of protein in different cuts of lamb. *J. Nutrition*, **43:** 3 (Mar. 1951).

Experiments were conducted with young male albino rats to determine whether the protein in dehydrated, raw lean lamb was deficient in cystine, methionine, leucine, isoleucine, phenylalanine or tryptophan when protein was fed at the 7.5% level. Lamb protein was found to be deficient only in cystine or methionine, and when either was added to the diet in the same quantity, more rapid growth and better utilization of protein resulted. When protein in the lean meat in the leg, shoulder, and entire carcass of lamb was fed to young male rats at the 7.5, 10.0, and 12.5% levels, the protein in the entire carcass was superior in growth-promoting value to that in the leg. In a later experiment with a different lot of lambs, when protein was fed at the 12.5 and 15% levels, no material differences were found between the values for the three cuts of lamb.—*The Wistar Institute.*

65. Hoffman, William Samuel and Gordon Charles McNeil. Nitrogen requirement of normal men on a diet of protein hydrolysate enriched with the limiting essential amino acids. *J. Nutrition*, **44:** 1 (May 1951).

Nitrogen balance experiments were performed in 7 normal male human subjects, first with a diet containing a lyophilized modified casein hydrolysate as the only significant source of nitrogen, then with the same hydrolysate fortified with enough DL-tryptophan, L-phenylalanine, and DL-methionine to make the pattern of essential amino acids equivalent to that found by Rose for minimum requirements in humans. The mean nitrogen requirement for equilibrium supplemented hydrolysate 38.5 ± S.D.2.1. The reduction of 26% was statistically significant. Nitrogen equilibrium with the unsupplemented product was reached when L-tryptophan and methionine were at the minimum found by Rose, but with the supplemented product all the essential amino acids were at twice the minima. Therefore the limiting factor for nitrogen equilibrium for the supplemented product appeared to be not the quantity of essential amino acid but the total nitrogen present. This conclusion was corroborated in a short experiment in which the addition of 15 mg. glycine changed from negative to positive the balance produced by 30 mg. per kg. per day of the supplemented hydrolysate.—*The Wistar Institute.*

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Nevada (0)
New Mexico (1) Frances McGill
Utah (1) Pauline Fuller

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Association for Physical and Mental Rehabilitation: Arthur D. Tauber
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Prepared by Index Committee of National Council of the Research Section
Marjorie Phillips, Chairman

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